SYSTEMS OF INTERIOR LIGHTING

BY

V. PAGLIARULO

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A COMPARATIVE INVESTIGATION OF DIFFERENT SYSTEMS OF INTERIOR LIGHTING

A THESIS

PRESENTED BY

V. PAGLIARULO

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Approved,
E. H. Freeman
Prof. of Elect. Eng.

L. C. Monin
Dean of Cult. Studies

F. M. Raymond
Dean of Eng. Studies

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INTRODUCTION

The scope of this thesis is to gather and present comparative data, on some recent lighting installations in the Electrical Engineering lecture room, of Armour Institute of Technology.

Considering the importance that the profession of Illuminating Engineering has recently attained, all data gathered from researches conducted under rigidly scientific methods, will add greatly to the development and furtherance of the profession. In the tests, upon which we intend to base this thesis, we propose to follow such methods as to iliminate, as much as it is possible, all sources of error, and make the results of the tests a truly valuable set of informations.

The problems with which the Illuminating Engineer has to contend are many sided, and are influenced by numerous factors. Foremost among these influencing factors are the economical, the physiological, and the psychological. The economical factor is of such magnitude as to leave, many times, out of consideration all the other factors. It is the most pressing from the consumer's

point of view, who is very much interested to see that he gets the maximum illumination with the least expenditure of energy. As to the physiological factor, a prominent oculist in this city has many times asserted that a certain theatre has been the mean of copious revenue to him on account of the archaic system of illumination. Helmholtz emphasized the fact that the effects of illumination upon the eyes are physiological rather than physical, therefore a prolonged strain upon the eyes, such as may result from long exposure in a badly illuminated room, is apt to produce serious injury. On the other hand, it is a fact that the illumination of a room or hall, has a decided effect upon an individual, making him feel cheerful or gloomy, according as the illumination is glittering bright or subdued.

Illumination installations must also harmonize with the surroundings. This we might put down as a general law in Illuminating Engineering. The illumination of a ball room, of a drawing room, or of a library, are specific problems, each one requiring a separate solu-

tion. There are other classes of service where the quality of the light, as well as the quantity, is a deciding factor. Take for instance a dry goods store, where it is essential that the color appearance of the goods be not changed from their day-light appearance.

We may now inquire, what constitutes the best illumination for a school lecture room ?. This question is by no means an easy one to answer properly. And there are, perhaps, no two illuminating experts who will answer it in the same way, or peremptorily agree on every point. We may start by putting down some items which are so essential to be beyomd discussion. A lecture room, for instance, must be as evenly illuminated as possible. A room that is equally illuminated all over, undoubtedly produces a more pleasing effect, than one which presents dark spaces and dark corners. That this is not an irrilevant item may be argued from the point that a school room "per se" is not a place where a student, speaking of the average type, stays with pleasure regardless of the appearance. It has to be made attractive to

him, in order that the natural adversion for the place be mitigated. Furthermore; in places where there is a wide variation in the brightness of objects, the observer will suffer a depression of visual functions, and due to the direct connection between the eyes and the brain, he is likely to suffer also a depression of brain functions, a reduction of his ability to learn, or pay sustained attention.

Besides being evenly illuminated, a school room must have enough light for every student to see clearly. It is true that the eyes are able to adjust themselves over a wide range of intensities, and as far as being able to see is concerned, we can see as well in a relatively dark room as in a brightly illuminated one, after the eyes have been accustomed to the light conditions. But to work in a dark room, where an effort must be made to see clearly, means a constant strain on the optic nerve, which eventually may lead to serious injury to the eyes. Analizing the conditions of the students who attend evening classes in the room under consideration, we find

that they are mostly young men who are amployed during the day, and who are willing to make an extra effort to further their education and advantages. Clearly, when they come to classes they are not in the best physical conditions to accrue knowledge, since the body and the eyes are tired after working an entire day. Then, if the additional tax is imposed of working in a room where the eyes are strained still more, the probabilities are that the high aims of the students are apt to end disastrously. We do not here intend to convey the idea that the room shall be lavishly, or wastefully illunimated. An illumination which shall strain the least the eyes of the students is what is desired. The best authorities give a uniform illumination of 2 to 3 foot-candles as necessary for a school lecture room.

Glare is a very undesirable phenomenon anywhere, much more undesirable in a lecture room. It depresses the visual functions, which, as was pointed out above, is a decided disadvantage. Without going into a scientific explanation of glare, let it be sufficient to say that

glare is practically due,to sources of too great intrinsic brilliancy within the field of view, or of too great absolute intensity at short distance. It is recognized among illuminating experts, that the specific brightness of the illuminating sources within the field of view must be kept within definite limits, under given conditions, to avoid eye strain.

Another undesirable phenomenon, at least as far as a school room is concerned, is perfect diffusion. In a school room is imperative that there be sharp definition of objects, especially during demonstrations of experiments from the lecture table, and also to give form and solidity to surroundings.

Recapitulating what we have said,regarding the proper illumination of a lecture room, we find the essential requirements to be: An even distribution of light on the working plane. A sufficiently high intensity on the working plane,for each student to work without unduely straining his eyes. There must not be any strong light sources within the angle of vision. Perfect diffusion

must be avoided. In the present case we will endeavor to determine which of the three lighting installations now in the room, more nearly approaches these conditions. Since the author is in no way connected with the concerns which have furnished the reflectors for the installations and is not under any obligation to them, perfectly impartial conclusions will be drawn from the results obtained from the tests.

DESCRIPTION OF THE ROOM

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The Electrical Engineering lecture room is located on the second floor of the main building,of Armour Institute of Technology. It is 27.5 ft. long, 23 ft. wide and 14.5 ft. high. On the east wall are four large windows, provided with shades and counter shades. On the south wall is a blackboard covering the central half of the wall, and on the west corner is a small switchboard panel. The west wall has the door near the north corner. On each side of the door is a blackboard, and near the south corner is a space 5 ft. square, painted

clear white, on which are projected the lantern slides. The north wall is for the entire length covered with blackboard 3 ft. wide. The room also contains a lecture desk, near the south wall, a lantern stool, a lantern and a number of chairs. A plan view of the room is given in figure 1.

The walls of the room, where they are not covered with blackboards and other apparatus, are painted with a yellowish-brown color. The ceiling is painted with a mellow cream color. The room has but recently been painted and is in an eccellent condition for such investigation as we propose to carry in it.

The ceiling has five outlets from which fixture are hung. There is one center outlet, and four other outlets, one in the center of each of the four quarter bays, in which the room was devided. The fixtures have been designed especially for this installation; so that the reflectors may be grouped on the center fixture, or distributed on the corner fixtures. The reflectors may also be hung downwards or turned upwards.

There are three lighting circuits leading to the fixtures, one for the center, one for the distributed fixtuures when the reflectors are hanging downwards, and one for the distributed fixtures when the reflectors are turned upwards. The circuits are controlled by means of push botton switches, the arrangement of which is such that only one circuit is alive at any one time.

TESTS

The tests will consist of finding the intensity of illumination on the working plane. The fixtures are so arranged, that the distance between the ceiling and the reflectors may be varied at will. It will be possible to determine, therefore, the distance of the reflectors from the ceiling, which will give the best illumination on the working plane.

Three different types of reflectors will be used in this investigation, as follows:

Four E-100 reflectors, furnished by the National X Ray Co. These reflectors will be used as an indirect

lighting system. The tests which we propose to carry on these reflectors are six, three when the reflectors are grouped on the center fixture, and three when they are distributed on the corner fixtures. A test will consist in obtaining the light distribution on the working plane when the reflectors are at a definite distance from the ceiling. With the reflectors grouped on the center fixture, the three tests will made when the reflectors are 3ft., 4 ft., and 5 ft., from the ceiling. With the reflectors distributed on the corner fixtures; the three tests will be made having the reflectors 2 ft., 3 ft. and 4 ft. from the ceiling.

The other type of reflectors which we will use are four #3445 Alba reflectors, furnished by the Macbeth-Evans Co. On these reflectors nine tests will be made, three when the reflectors are grouped on the center fixture, the reflectors turned upwards, the edge of the reflectors being 3 ft., 4 ft., and 5 ft. from the ceiling. Three more tests will be made,with the reflectors distributed on the corner fixtures and turned upwards, the edge of

the reflectors being 2 ft., 3 ft., and 4 ft. from the ceiling. The other three tests will be made, with the reflectors distributed on the corner fixtures and turned downwards, the edge of the reflectors being 3.75 ft. 4.75 ft., and 5.75 ft. from the ceiling.

The other type of reflectors which we will investigate is type F -150, satin finish, furnished by the Holophane Co. The tests performed on these reflectors will be essentially the same as those performed on the Albea reflectors, one for one.

CONDITIONS OF THE TESTS

Since this will be a comparative investigation, in order to be fair to all concerned, the tests will be made under identical conditions. Accordingly, four 150 watts, wire drawn filament, tungsten lamps were chosen to light the room. These lamps were new lamps, but had been burned more than 50 hours before using them in the tests, in order to insure a nearly constant candle-pwer for the duration of the tests. The lamps, as appears

from the calibration data, were of nearly the same candle power.

The candle power of the lamps was determined in the usual manner. In order to eliminate errors due to color differences of the light sources, a 25 c.p. tungsten lamp was used as a standard of comparison, this lamp having previously been standardized with a 16 c.p. carbon lamp standardized by the Bureau of Standards. A Lummer-Brodhun contrast photometer screen was used to obtain the photometric balance. In calibrating the lamps to find the mean horizontal candle power (M.H.C.P.), they were rotated through a small angle about a vertical axis. The candle power intensity all around the lamp was found to be about the same, as is shown in tables II to IV inclusive. Multiplying the M.H.C.P. thus found, by the reduction factor, which for these lamps is .79, as determined by the manufacturers, the M.S.C.P. was obtained. The total lumens emitted by the lamp is, its M.S.C.P. multiplied by 4π. The voltage impressed upon the lamps

which remained constant during the tests, was 110 volts as measured by a standardized Weston voltmeter. To maintain a constant voltage across the lamps, advantage was taken of the use of a storage battery as a source of power. This saved much work in correcting the test readings for variation of voltage, which would be required if the lamps were lighted with power derived from the generator, the voltage of which is subject to wide variation. Table I gives the calibration of the comparison 25 c,p. lamp. Tables II to V inclusive gives the results of the calibration of the four cervice lamps.

The photometer used during the tests was a Sharp and Millar universal photometer. It was calibrated to read directly in foot candles, by placing the test plate exactly 4 ft. away from the filament of the standard 16 c.p. carbon lamp. That we shoud get this intensity of illumination at that distance from the lamp is readily apparent from a consideration of the definition of foot candle, and the physical fact, that the intensity of illumination varies inversely as the square of the dis-

tance from the source. Since one foot candle is the intensity of light falling normally on a surface one foot away from the source of one candle intensity, and

$$\text{Intensity} \propto \frac{1}{d^2}$$

then

$$\frac{1}{1^2} = \frac{16}{4^2} = 1$$

To make the photometer read directly, besides placing the test plate at the proper distance from the standard lamp, the index of the scale was placed on the 1.00 foot candle mark of the photometer scale. The voltage of the standard lamp was adjusted to the proper value to give 16 c.p., and the photometer balance was now obtained by varying the voltage impressed on the photometer lamp by means of a rheostat. A constant voltage was maintained across the standard lamp by connecting it to the storage battery. The photometer lamp was connected to 2 storage cells in series. The pressure across the terminals of t the photometer lamp was measured by means of a Weston millivoltmeter.

The floor of the room in which the tests were made was devided into four equal sections. Since the lighting fixtures are symmetrically placed, and the lamps are of nearly the same candle power, the light survey made in one quarter section will be the same as that of the other sections, with respect to the center lines of the room. The north east section was chosen (see fig. 1) for no other reason than that of accessibility, and freedom from interference. The section chosen was subdevided in thirty squares 2.3 × 2.3 ft. and a test station located in the center of each square.

The room is one which is daily used for lecture purposes. During the tests; none of the furniture or apparatus which is permanently in the room was removed. The chairs are of a dark oak color. During the tests, they were put together on one side of the room. The lecture table the lantern stool, the floor, and the door are of a light oak color. The ceiling is of a light cream color, and has been but recently painted. The walls, also but recently painted, where they are not covered with blackboards, are

of a yellowish- brown color. Two shades were used on each window, to reduce the amount of light admitted into the room by specular reflection. It was found, that with the present arrangement of shades, a small amount of light still creeps in from around the periphery of the window. An attempt was made to measure the amount of this stray light, and make the ppoper corrections in the actual readings; but the plan had to be abandoned on account of the impossibility of measuring this light with any degree of accuracy, so small was its intensity. In any case, it only introduces a very small error varying from about .5% in the readings taken in the stations near the center of the room, to about 1% in the readings taken in the stations nearer the windows. Also, since the tests were made in the afternoon, between 2 p.m. and 7 p.m., the percent of error varies from a maximum to zero, as the evening approaches. The color of the inner shades is of a greenish-yellow.

The plane of reference was taken, as a horizontal plane 30 inches above the floor.

The reflectors were kept thoroughly clean during the tests. Incidentally it was noticed, that with the Holophane reflectors, an error of about 25% is introduced by having the reflectors covered with dust. With the X Ray reflectors this error increases to about 35%.

On account of the many precautions taken to eliminate errors, it is believed that the results obtained in these tests are within 3% of actual values. The measuring instruments, such as voltmeters and ammeters, and the photometer, were recalibrated frequently to guard against errors creeping in. Three readings were taken at each station by the same observer, and in the tables the arithmetical mean of these readings is given.

COMPARISON OF RESULTS

All the twenty four tests performed, may be devided in eight groups, each group embodying those tests performed on one type of reflectors when operating at different distances from the ceiling.

Group One: This group consists of the tests

performed on the XRay reflectors when placed on the center fixture. The results of the tests are given in tables VI to XIX inclusive. The distribution curves for the same group are given in figures 1 to 6 inclusive.

The characteristic features of this group are as follows: The intensity of illumination is high right under the reflectors, and decreases rether rapidly as the horizontal distance from the center of the room increases. The variation of intensity is, however, uniform;so that a great contrast of illumination intensities is avoided. The intensity becomes entirely too low, for any student to work with comfort for any length of time, about seven feet from the center of the room . The zone of usefulness these reflectors used in this manner is, therefore, limited. The highest intensity attained is 3.5 foot candles, right under the fixture, as is shown in the tables and curves. The lowest intensity is .75 foot candles, in the farthest corners of the room.

The highest intensity is attained when the reflectors are 2 ft, from the ceiling. At this distance, however, the

rate of decrease of the intensity, as the horizontal distance from the center of the floor is increased, is the greatest. Glancing at the curves for this group we see,that the distribution curve for this test cuts the curves of all the other tests before reaching the edge of the floor. In our opinion, the best results ~~for~~ with these reflectors are obtained when they are hung 3 ft. from the ceiling. Though the rate of decrease of intensity, when the reflectors are so placed, is a little higher than when they are placed 4 ft. or 5 ft. from the ceiling the intensity is also higher all along. The average intensity on the working plane, being the mean of all the thirty readings of the test stations, does not change appreciably, as may be seen from the tables, as the distance of the reflectors from the ceiling is changed, eccept when they are five feet from the ceiling, when the average intensity falls off about 10%. The highest operating efficiency of this group is attained,when the reflectors are 3 ft. from the ceiling.

GROUP TWO: This group consists of the tests performed on the X Ray reflectors, when distributed on the corner fixtures. The results of these tests are given in tables X to XII inclusive, and the distribution curves for the same group are given in figures 7 to 12 inclusive.

The characteristic features of this group are as follows: The intensity is good in the center of the room, and it remains so, as the edge of the floor is approached. The distribution curves of this group are flat, indicating that the rate of change of intensity as we go farther from the center of the room, is not so high. Within the area in which the students are seated, the intensity of the light is sufficiently high for any student, whose eyes are not defective, to be able to work without discomfort. The zone of usefulness of these reflectors when used in this manner is large, much larger than when they are placed on the center fixture.

The highest intensity attained is 2.5 foot candles in the center of the room, as is shown in the tables and in the distribution curves. The lowest intensity is

1.1 foot candles. The highest intensity is attained, when reflectors are 4 ft. from the ceiling; but again, when the reflectors are at this distance, the decrease of light intensity, as the distance from the center of the room is increased, is most rapid.

In our opinion, the best results are obtained with the reflectors so used, when they are placed 3 ft. from the ceiling. The variation of intensity is not great, any way, as the distance between the reflectors and the ceiling is changed, and the preference of placing them 3 ft. from the ceiling is merely one of appearance. The average foot candle intensity on the working plane; that is; the mean of the thirty readings taken in the test stations, does not change at all, in the range of our tests, as the distance between the refledtors and the ceiling is changed. Whatever change there is, it is certainly less than the experimental error. The Highest operating efficiency of this group is attained, when the refledtors are 2 ft. from the ceiling. The change of efficiency, from placing the reflectors 2 ft. from the

ceiling, to placing them 3 ft., however, is negligible and the sacrifice may cetainly be made for the sake of appearance.

GROUP THREE: This group consists of the tests performed on the Alba reflectors,when placed on the center fixture, turned upwards. Thus placed the reflectors act as a semi-indirect system of illumination. The results of the tests are given in tables XIII to XV inclusive and the distribution curves are given in figures 13 to 17 inclusive.

The characteristic features of this group are as follows; Very high intensity in the center of the room decreasing very rapidly as the distance from the center of the room is increased. The variation is so rapid that the intensity near the edges of the floor is hardly sufficient for any normal student to work with comfort. The distribution curves are very peaked, and show very well how high the rate of change of intensity is. Within the area where the students seat, the intensity is high but variable. This is not a good feature,

permitting a considerable waste of energy, by throwing considerably more light than is desired in a limited zone, while in other zones the light is less than sufficient.

The highest intensity attained with these reflectors used in this manner is 7.55 foot candles in the center of the room. The lowest intensity is 1.05 foot candles. The highest intensity is attained, when the edge of the reflectors is 5 ft. from the ceiling, but at this distance the rate of decrease of light intensity is also the greatest, as the distance increases from the center of the room.

Since within the useful zone the intensity is sufficiently high, whether the reflectors are three, four, or five feet from the ceiling, it appears to us that by having them three feet from the ceiling is the best arrangement. It is true, that at that distance the average intensity is lower than if the distance was five feet, but the appearance is better. Furthermore, with the reflectors placed five feet from the ceiling, they are fully

within the angle of view of those students who seat in the back rows, who thus have to suffer the objectionable effects of glare.

there is an appreciable change in the average foot candle intensity, when the reflectors are placed three, four, or five feet from the ceiling. The highest operating efficiency of this group is attained when the reflectors are placed 5 ft. from the ceiling.

GROUP FOUR: This group consist of the tests performed on the Alba reflectors, when placed on the fixtures distributed in the four bays, turned downwards. The reflectors arranged in this manner act as direct system of illumination. The results of the tests for this group are given in tables XVI to XVIII inclusive, and the distribution curves are given in figures 19 to 24 inclusive.

Among the characteristic feature of this group we note the following: The distribution is almost ideally even, when the refledtors are no more than four feet from the ceiling. The change of intensity from the center of

the room, where it is the highest, to the edge of the floor, where it is the lowest, is first of all small, it is, furthermore, so gradual as to be unnoticeable to the eyes. The intensity is also higher than it is required for a school lecture room. The zone of usefulness of these reflectors, when used as described above, embraces the entire room. Nowhere, eccept in the extreme corners the intensity is so low, as to make any normal student uncomfortable while working.

The highest intensity attained is 4.4 foot candles right under the lamps. the lowest intensity is 1.75 foot candles in the extreme corners of the room. The highest intensity is attained when the reflectors are 5 ft. 8 in. from the ceiling. In the center of the room, however, the intensity is higher when the reflectors are 4 ft. 8 in. from the ceiling. This is due to the fact that in hanging the reflectors nearer the working plane, they shield and absorb more of the direct light coming from the incandescent filament of the lamps. This is very well shown in figures 19 to 23, where the curve of light distribution

with the reflectors placed 5 ft. 8 in. from the ceiling is seen to be lobed, while the other curves are smooth.

In this case again, in order to avoid the effects of glare in the eyes of those students s~~ea~~itting in the back rows, it is more convenient to sacrifice the highest efficiency on the altar of comfort, and place the reflectors 3 ft., 8 in. from the ceiling. The highest operating efficiency of this group is attained, when the reflectors are 5 ft., 8 in. from the ceiling.

GROUP FIVE: This group consists of the tests performed on the Alba reflectors, when placed on the fixtures in the four quarter bays, turned upwards. The reflectors arranged in this manner act as a semi-indirect system of illumination . The results of the tests for this group are given in tables XIX to XXI inclusive, and the distribution curves are given in figures 25 to 30 inclusive.

The characteristic features of this group are essentially the same as those of group four. The distribution is again very even, and the rate of decrease of intensity is negligible. The intensity is sufficiently high, being

well within the limits prescribed by the best authorities on illumination. The effects of glare may also be considered as negligible, as the incandescent filaments of the lamps are completely shielded by the opaque reflectors. The absence of lobed curves is a noticeable feature of the distribution curves.

The highest intensity attained with the Alba reflectors used in this manner is 3.8 foot candles in the center of the room, and the lowest intensity is 1.5 foot candles in the extreme corners. The distance of the reflectors from the ceiling does not affect,"either the average intensity of illumination on the working plane nor the smoothness of the distribution. The most suitable arrangement, in our opinion, is when the reflectors are placed 4 ft. from the ceiling.

GROUP SIX: This group consists of the tests performed on the Holophane reflectors, when placed on the fixture in the center of the room, turned upwards. The reflectors arranged in this manner act as semi-indirect system of illumination . The results of the tests for this group

are given in tables XXII to XXIV inclusive, and the distribution curves are given in figures 31 to 36 inclusive.

In the characteristic features of this group may be noted the following points: The intensity is very high in the center of the room and decreases very rapidly towards the wall. Here again we find an intensity unnecessarily too high in one place, and decidedly low in other places where we still need a high intensity. The distance of the reflectors from the ceiling has very little effect on the distribution of the light, or on its intensity, as is well shown by the distribution curves.

The highest intensity attained with these reflectors is 4.1 foot candles in the center of the room, and the lowest intensity is 1 foot candle in the farthest corners. With the reflectors placed 5 ft. from the ceiling the highest intensity is attained. The rate of change of intensity is also greatest, at this distance of the reflectors from the ceiling.

For the same reasons given in the discussion on the

previous groups, the reflectors, in our opinion, should be placed three feet from the ceiling for the best arrangement. The operating efficiency of this group is greatest when the reflectors are 5 ft. from the ceiling.

_GROUP_SEVEN_: This group consists of the tests performed on the Holophane reflectors, when placed on the fixture in the four quarter bays, turned downwards. In this arrangement the reflectors act as a direct system of illumination. The results of the tests for this group are given in tables XXV to XXVII inclusive, and the distribution curves are given in figures 37 to 42 inclusive.

The features of this group are the following: The distribution is extremely uneven, the intensity varying from eccessive, right under the lamps, to barely sufficient around the border of the room. The high intensity however, within the useful zone makes this arrangement of reflectors a very commendable one. The most objectionable feature of these reflectors, when used in this manner, is the presence of glare, which is produced by the high intrinsic brilliancy of the edges of the refracting

prisms. With this system glare is unavoidable, no matter how high the reflectors are placed. The contrast is so great, between the high intrinsic brightness of the edges of the prisms and the rest of the surroundings, to be a constant source of distraction to the students.

Another marked feature of the group is the appreeciable difference in intensity and distribution, when the distance between the reflectors and the ceiling is varied. The highest intensity, 6.6 foot candles, is obtained when the reflectors are 5 ft. from the ceilng. The glare effects at this distance, however, is so great as to make the arrangement altogether impractical. The reflectors should be as near the ceiling as is possible to put them to minimize the effects of glare. The highest efficiency is also attained when the reflectors are 5 ft., 8 in. from the ceiling.

GROUP EIGHT: This group consists of those tests performed on the Holophane reflectors, when placed on the fixtures in the four quarter bays, turned upwards. The reflectors thus used constitute a semi-indirect system

of illumination. The results of the tests for this group are given in tables XXVIII to XXX inclusive, and the distribution curves are given in figures 43 to 48 inclusive.

Among the predominating features of this group we note that the intensity is anywhere hardly sufficient for the purpose. The zone of usefulness of these reflectors arranged in this manner is very, very limited making this arrangement impractical. Another very objectionable feature is the predominance of glare. The efficiency is decidedly low.

This completes the discussion on single groups. We may now compare the features of the three types of reflectors when operating under the same conditions. Beginning with the arrangement when the reflectors are grouped on the center fixture, we note that with this arrangement any type of reflectors under tests, whether X Ray, Alba, or Holophane, gives a decidedly bad distribution. The X Ray reflectors, even when at their best, do not give a sufficiently high intensity at some distance from the center of the room to make them practical. In

our opinion, the X Ray reflectors are at a great disadvantage when compared with the other reflectors. The Alba reflectors, although giving a bad distribution, maintain a sufficiently high intensity in any part of the room for any student to work with comfort. Another commendable feature of the Alba reflectors is the almost complete absence of glare, especially if they are placed near the ceiling. The Holophane reflectors besides the bad distribution present the objectionable feature of glare. The high intrinsic brilliancy of the edges of the prisms is always in evidence, no matter how near the ceiling the reflectors are put. Economically the Alba reflectors have the advantage over the other types, possessing a higher efficiency. The physiological factor is also in favor of the Alba reflectors, presenting no glare effects. The X Ray reflectors are also commendable in this respect, because they give a very soft light effect, free from glare or strong contrast in wide difference of intensity of illumination. The objection frequently advanced against the X Ray reflectors, as producing a gloomy and depressing

effect upon the observer, is certainly absent in this case. The real objection lies in the comparatively low efficiency of the reflectors. Had these reflectors a little higher efficiency, which would mean a higher average intensity of illumination on the working plane they would surely make the most acceptable system of illumination . As it is, they must give way to the Alba reflectors, at least as far as the illumination of this room is concerned.

Analizing the comditions when the Alba and the Holophane reflectors are ~~placd~~ placed on the four quarter bay fixtures, turned ~~upwards~~ downwards, or, in other words, when acting as a direct lighting system, we notice that the Alba reflectors again have the advantage. The average intensity on the working plane is higher, it is true, with Holophane reflectors, making them have the higher operating efficiency, but it is also true that when the efficiency is the greatest,they produce the most objectionable glare effects. The light distribution on the working plane is by far better with the Alba reflectors. Un this case

the distribution is almost ideal, while the light distribution due to the Holophane reflectors is very uneven, as is well shown by the respective distribution curves. Economically the Holophane reflectors have a decided advantage over the Albas, physiologically they are at a great disadvantage. We do not intend ~~here~~ here to convey the idea that the Alba reflectors, when used in this manner, produce a perfect systen of illumination in every respect. They have, in fact, some objectionable features, such as some amount of glare from the bare incandescent filament of the lamps, but this defect is more predominating in the Holophane reflectors. As to the effect that the two types of reflectors produce on the observer, there is no great difference. Aesthetically they are both pretty.

When the three types of reflectors are placed on the fixtures ~~placed~~ on the four quarter bays, the X Ray reflectors acting as a totally indirect system of illumination, and the Alba and Holophane reflectors acting as semi-indirect systems, the comparison is again in favor of the Alba

reflectors. We may peremptorily discard the Holophane reflectors from this group, as being the lowest in efficiency and physiologically objectionable. As between the Alba and the X Ray reflectors, the ~~latter~~ former are to be preferred, for no other reason than that of higher efficiency. The appearance of the room, lighted with the Alba reflectors, is a little more cheerful than when it is lighted with the Holophane or X Ray reflectors.

GENERAL CONCLUSIONS

The following general conclusions may be drawn as the result of this research:

From the point of view of illuminating efficiency, the Holophane reflector is more desirable than the other types of illuminating units. This good point is, however completely offset by the predominance of glare. The X Ray reflectors, if used at all, should be used distributed in the four quarter bays, and should be provided with lamps of a higher rating than 150 watts. These reflectors lose much of their worth if dust is allowed to accumulate on

their polished surface, consequently their cost of maintenance is considerably higher than any of the other two types of reflectors. The Alba reflectors give the best satisfaction under the circumstances, Their efficiency is high, their glare effect is negligible, and they look good. Preferably they should be used distributed on the four quarter bay fixtures, turned downwards.

TABLE I

°°°0°°°

Calibration of comparison tungsten lamp.

Standard carbon lamp gives 16 C.P. at 116.1 volts.

Voltage impressed on comparison lamp = 110.5 volts.

Distance of photometer screen from standard lamp = 40 cm.

" " " " " " " comparison " = 50 cm.

$$\text{C.P. of comparison lamp} = \frac{16 \times 50^2}{40^2} = 25$$

TABLE II

Calibration of lamp # 1

Voltage impressed on comparison lamp = 110.5 volts.

Voltage impressed on cervice lamp = 110 volts.

Distance of standard lamp from screen = 50 cms.

Distance of service lamp from screen = D.S. cms.

Horizontal angle through which lamp was turned = ϕ

ϕ	D.S.	ϕ	D.S.	ϕ	D.S.
0	103	120°	104.2	240°	105.4
30°	102.8	150°	104.3	270°	105.8
60°	102.5	180°	104.5	300°	105.0
90°	104.1	210°	105.5	330°	104.8

Average distance of lamp from screen = 104.3 cms.

C.P. of lamp = $\frac{25 \times 104.3^2}{50^2} = 109$

Reduction factor of lamp = .79

M.S.C.P. = $.79 \times 109 = 86.11$

Total lumens emitted by lamp = $4 \times 3.14 \times 86.11 = 1082.5$

Current in lamp = 1.32 amps.

Observed lumens per watt = $\frac{1082.5}{110 \times 1.32} = 7.47$

TABLE III

°°°o°°°

Calibration of Lamp # 2

Voltage impressed on comparison lamp = 110.5 volts

voltage impressed on service lamp = 110 volts.

Distance of standard lamp from screen = 50 cms.

Distance of service lamp from screen = D.S. cms.

Horizontal angle through which the lamp was turned=Ø°

Ø	D.S.	Ø	D.S.	Ø	D.S.
0	107.4	120°	105.5	240°	106.0
30°	106.5	150°	106.0	270°	108.5
60°	105.8	180°	108.7	300°	108.9
90°	106.5	210°	106.0	330°	108.7

average distance of lamp from screen = 107 cms.

Horizontal candle power of lamp = $\frac{25 \times 107^2}{50^2}$ = 114.5

Reduction factor of lamp = .79

Mean spherical candle power = .79 × 114.5 = 90.5

Total lumens emitted by lamp = 4 × 3.14 × 90.5 = 1140

Current in lamp = 1.47 amps.

Lumens per watt = $\frac{1140}{110 \times 1.47}$ = 7.05

TABLE IV

Calibration of Lamp # 3

Voltage impressed on comparison lamp = 110.5 volts.

Voltage impressed on service lamp = = 110 volts.

Distance of standard lamp from screen = 50 cms.

Distance of srevice lamp from screen = D.S. cms.

Horizontal angle through which lamp was turnad = Ø

Ø	D.S.	Ø	D.S.	Ø	D.S.
0	105.5	120°	104.3	240°	103.0
30°	105.0	150°	104°.7	270°	104.2
60°	105.5	180°	105.0	300°	104.0
90°	101.5	210°	105.0	330°	103.3

Average distance of lamp from screen = 104.3 cms.

Mean horizontal candle power = $\dfrac{25 \times 104.3^2}{50^2} = 109$

Reduction factor of lamp = .79

Mean spherical candle power = .79 × 109 = 86.11

Total lumens emitted by lamp = 4 × 3.14 × 86.11 = 1083.5

Current in lamp = 1.37 amps.

Lumens per watt = $\dfrac{1082.5}{110 \times 13.7} = 7.2$

TABLE V

Calibration of Lamp # 4

Voltage impressed on comparison lamp = 110.5 volts

Voltage impressed on service lamp = 110 volts

Distance of standard lamp from screen = 50 cms.

Distance of service lamp from screen = D.S. cms.

Horizontal angle through which lamp was turned = Ø

Ø	D.S.	Ø	D.S.	Ø	D.S.
0	104.4	120°	106.0	240°	103.2
30°	105°0	150°	106.4	270°	106.5
60°	104.5	180°	103.7	300°	106.7
90°	106.4	210°	103.7	330°	103.0

Average distance of lamp from screen = 105 cms.

Mean horizontal candle power = $\dfrac{25 \times 105^2}{50^2} = 110.5$

Reduction factor of lamp = .79

Mean spherical candle power = .79×110.5 = 87.3

Total lumens emitted by lamp = 4×3.14×87.3 = 1100

Current in lamp = 1.325 amps.

Lumens per watt = $\dfrac{1100}{1.325 \times 110} = 7.55$

TABLE VI

°°0°°

Four E-100, National X Ray reflectors, in center of room, equipped with 150 watts tungsten lamps.

Distance of edge of reflectors from ceiling = 2 ft.

Lamps voltage = 110 volts.

Lamps current = 5.45 amps.

Photometer millivoltmeter reading = .922

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	3.49	11	2.80	21	1.68
2	3.15	12	2.59	22	1.56
3	2.80	13	2.30	23	1.35
4	2.18	14	1.83	24	1.15
5	1.70	15	1.50	25	1.02
6	1.60	16	1.23	26	.71
7	2.03	17	1.45	27	.83
8	2.60	18	1.70	28	1.00
9	2.96	19	2.10	29	1.12
10	3.27	20	2.17	30	1.15

Average F.C. intensity = 1.90

TABLE VII

* * *

Foyr E-100, National X Ray reflectors, in center of room,equipped with 150 watts tungsten lamps.

Distance of edge of reflectors from ceiling = 3 ft.

Lzmps voltage = 110 volts.

Lamps current = 5.43 amps.

Photometer millivoltmeter reading = .922

* * *

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	3.40	11	2.87	21	1.68
2	3.13	12	2.54	22	1.60
3	2.75	13	2.22	23	1.38
4	2.25	14	1.82	24	1.22
5	1.80	15	1.42	25	1.03
6	1.64	16	1.17	26	76
7	2.10	17	1.50	27	.91
8	2.57	18	1.85	28	1.06
9	3.00	19	2.08	29	1.17
10	3.25	20	2.22	30	1.25

Average F.C. intensity = 1.92

TABLE VIII

* * *

Four E-100, National X Ray reflectors, in center of room, equipped with 150 watts tungsten lamps.

Distance of edge of reflectors from ceiling = 4 ft.

Lamps voltage = 110 volts.

Lamps current = 5.45 amps.

Photometer millivoltmeter reading = .922

* * *

Sta.	F.C.Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	3.22	11	2.73	21	1.70
2	3.02	12	2.55	22	1.63
3	2.67	13	2.23	23	1.43
4	2.25	14	1.73	24	1.18
5	1.77	15	1.39	25	.99
6	1.60	16	1.20	26	.79
7	2.02	17	1.51	27	.92
8	2.42	18	1.82	28	1.97
9	2.90	19	2.05	29	1.18
19	3.00	20	2.22	30	1.23

Average F.C. intensity = 1.91

TABLE IX

°°°0°°°

Four E-100, National X Ray reflectors, in center of room equipped with 150 watts tungsten lamps.

Distance of edge of reflectors from ceiling = 5 ft.

Lamps voltage = 110 volts.

Lamps current = 5.45 amps.

Photometer millivoltmeter reading = .922

°°°0°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	3.00	11	2.55	21	1.65
2	2.90	12	2.35	22	1.56
3	2.45	13	2.10	23	1.88
4	2.05	14	1.78	24	1.20
5	1.67	15	1.38	25	.98
6	1.55	16	1.20	26	.78
7	2.00	17	1.52	27	.92
8	2.35	18	1.77	28	1.03
9	2.60	19	2.00	29	1.17
10	2.80	20	2.15	30	1.23

Average F.C. intensity = 1.80

TABLE X

* * *

Four E-100 National X Ray reflectors, equipped with 150 watts tungsten lamps, distributed in corners.

Distance of edge of reflectors from ceiling = 3 ft.

Lamps voltage = 110 volts.

Lamps current = 5.45 Amps.

Photometer millivoltmeter reading = .922

* * *

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	2.30	11	2.18	21	1.95
2	2.30	12	2.22	32	1.88
3	2.20	13	2.10	23	1.77
4	2.05	14	1.94	24	1.65
5	1.78	15	1.68	25	1.43
6	1.70	16	1.54	26	1.16
7	1.95	17	1.85	27	1.20
8	2.10	18	2.00	28	1.51
9	2.20	19	2.10	29	1.58
10	2.30	20	2.18	30	1.54

Average F.C. Intensity = 1.88

TABLE XI

°°°0°°°

Four E-100, National X Ray reflectors, equipped with 150 watts tungsten lamps, distributed in bays.

Distance of edge of reflectors from ceiling = 3 ft.

Lamps voltage = 110 volts

Lamps current = 5.43 amps.

Photometer millivoltmeter reading = . 94

°°°0°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	2.32	11	2.15	21	1.90
2	2.30	12	2.15	22	1.80
3	2.25	13	2.08	23	1.73
4	2.05	14	1.92	24	1.60
5	1.80	15	1.65	25	1.40
6	1.80	16	1.50	26	1.12
7	2.05	17	1.78	27	1.26
8	2.22	18	2.00	28	1.45
9	2.30	19	2.10	29	1.55
10	2.30	20	2.10	30	1.55

Average F.C. intensity = 1.87

TABLE XII

°°°o°°°

Four E-100 National X Ray reflectors, equipped with 150 watts tungsten lamps, distributed in bays.

Distance of edge of reflectors from ceiling = 4 ft.

Lamps voltage = 110 volts.

Lamps current = 5.44 amps.

Photometer millivoltmeter reading = ..94

°°°o°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	2.48	11	2.25	21	1.80
2	2.38	12	2.10	22	1.73
3	2.28	13	2.00	23	1.66
4	2.10	14	1.90	24	1.54
5	1.80	15	1.57	25	1.33
6	1.77	16	1.45	26	1.07
7	2.12	17	1.71	27	1.25
8	2.30	18	1.90	28	1.42
9	2.35	19	2.10	29	1.47
10	2.40	20	2.12	30	1.55

Average F.C. intensity = 1.86

TABLE XIII

°°°0°°°

Four #3445 Alba reflectors, equipped with 150 watts tungsten lamps, in center of room, turned upwards.

Distance of edges of reflectors from ceiling = 3 ft.

Lamps voltage = 110 volts.

Lamps current = 5.45 amps.

Photometer millivoltmeter reading = .94

°°°0°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	5.90	11	4.10	21	2.05
2	5.03	12	3.65	22	1.94
3	4.10	13	3.00	23	1.80
4	3.10	14	2.55	24	1.54
5	2.40	15	1.98	25	1.32
6	2.25	16	1.49	26	1.05
7	2.90	17	1.87	27	1.17
8	3.77	18	2.20	28	1.37
9	4.55	19	2.63	29	1.46
10	5.10	20	2.83	30	1.60

Average F.C. intensity = 2.70

TABLE XIV

°°°0°°°

Four #3445 Alba reflectors, equipped with 150 watts tungsten lamps, in center of room, turned upwards.

Distance of edge of reflectors from ceiling = 4 ft.

Lamps voltage = 110 volts.

Lamps current = 5.45 amps.

Photometer millivoltmeter reading = .94

°°°0°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	6.65	11	4.14	21	2.05
2	5.45	12	3.65	22	1.95
3	4.22	13	3.06	23	1.80
4	3.06	14	2.47	24	1.49
5	2.43	15	2.05	25	1.27
6	2.23	16	1.53	26	1.00
7	2.90	17	1.93	27	1.17
8	3.70	18	2.33	28	1.38
9	4.75	19	2.67	29	1.45
10	5.65	20	2.84	30	1.60

Average F.C. intensity = 2.67

TABLE XV

* * *

Four #3445 Alba reflectors, equipped with 150 watts tungsten lamps, in center of room, turned upwards.

Distance of edge of reflectors from ceiling = 5 ft.

Lamps voltage = 110 volts.

Lamps current = 5.45 amps.

Photometer millivoltmeter reading = .94

* * *

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	7.20	11	4.20	21	2.90
2	5.80	12	3.65	22	1.95
3	4.30	13	3.10	23	1.75
4	4.00	14	2.37	24	1.46
5	2.42	15	1.82	25	1.25
6	2.22	16	1.54	26	.98
7	2.90	17	1.95	27	1.17
8	3.70	18	2.38	28	1.38
9	4.85	19	2.70	29	1.45
10	5.90	20	2.94	30	1.60

Average F.C. intensity = 2.83

TABLE XVI

* * *

Four #3445 Alba reflectors, equipped with 150 watts tungsten lamps, distributed in bays, direct lighting.

Distance of edge of reflectors from ceiling = 3 ft. 8 in.

Lamps voltage = 110 volts.

Lamps current = 5.45 amps.

Photometer millivoltmeter reading = .94

* * *

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	3.25	11	3.30	21	2.60
2	3.30	12	3.30	22	2.70
3	3.20	13	3.36	23	2.70
4	2.90	14	3.35	24	2.60
5	2.60	15	2.70	25	2.13
6	2.70	16	2.50	26	1.72
7	3.10	17	3.25	27	2.00
8	3.30	18	3.15	28	2.13
9	3.30	19	3.03	29	2.19
10	3.30	20	3.05	30	2.15

Average F.C. intensity = 2.83

TABLE XVII

°°°0°°°

Four #3445 Alba reflectors, equipped with 150 watts tungsten lamps, distributed in bays, direct lighting.

Distance of edge of reflectors from ceiling = 4 ft. 8 in.

Lamps Voltage = 110 volts.

Lamps current = 5.45 Amps.

Photometer millivoltmeter reading = .94

°°°0°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	3.35	11	3.30	21	2.70
2	3.25	12	3.45	22	2.80
3	3.25	13	3.45	23	2.80
4	3.00	14	3.60	24	2.80
5	2.55	15	2.75	25	2.20
6	2.60	16	2.65	26	1.68
7	3.18	17	3.40	27	1.95
8	3.35	18	3.35	28	2.20
9	3.35	19	3.35	29	2.10
10	3.40	20	3.15	30	2.15

Average F.C. intensity = 2.97

TABLE XVIII

°°°0°°°

Four #3445 Alba reflectors, equipped with 150 watts tungsten lamps, distributed in bays, direct lighting.

Distance of edge of reflectors from ceiling = 5 ft. 8 in.

Lamps voltage = 110 volts.

Lamps current = 5.45 amps.

Photometer millivoltmeter reading = .94

°°°0°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	3.20	11	3.40	21	2.90
2	3.30	12	3.85	22	3.00
3	3.30	13	3.90	23	3.20
4	3.10	14	3.85	24	2.90
5	2.70	15	2.85	25	2.30
6	2.80	16	2.70	26	1.65
7	3.20	17	3.60	27	2.05
8	3.43	18	3.50	28	2.30
9	3.50	19	3.80	29	2.25
10	3.25	20	3.30	30	2.18

Average F.C. intensity = 3.04

TABLE XIX

°°°0°°°

Four #3445 Alba reflectors, equipped with 150 watts tungsten lamps, distributed in bays, turned upwards.

Distance of edge of reflectors from ceiling = 2 ft.

Lamps voltage = 110 volts.

Lamps current = 5.45 amps.

Photometer millivoltmeter reading = .94

°°°0°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	2.70	11	2.70	21	2.25
2	2.70	12	2.70	22	2.30
3	2.65	13	2.68	23	2.18
4	2.50	14	2.47	24	2.05
5	2.20	15	2.12	25	1.78
6	2.18	16	2.02	26	1.47
7	2.50	17	2.40	27	1.68
8	2.80	18	2.68	28	1.83
9	2.70	19	2.70	29	1.85
10	2.80	20	2.58	30	1.88

Average F.C. intensity = 2.33

TABLE XX

* * *

Four #3445 Alba reflectors, equipped with 150 watts tungsten lamps, distributed in corners, turned upwards.

Distance of edge of reflectors ffom ceiling = 3 ft.

Lamps voltage = 110 volts.

Lamps current = 5.45 amps.

Photometer millivoltmeter reading = .94

* * *

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	2.80	11	2.75	21	2.30
2	2.72	12	2.78	22	2.28
3	2.65	13	2.75	23	2.22
4	2.63	14	2.60	24	2.08
5	2.25	15	2.23	25	1.79
6	2.25	16	2.05	26	1.47
7	2.50	17	2.45	27	1.73
8	2.63	18	2.67	28	1.89
9	2.73	19	2.64	29	1.92
10	2.75	20	2.64	30	1.87

Average F.C. intensity = 2.37

TABLE XXI

°°°0°°°

Four #3445 Alba reflectors, equipped with 150 watts tungsten lamps, distributed in bays, turned upwards.

Distance of edge of reflectors from ceiling = 4 ft.

Lamps voltage = 110 volts.

Lamps current = 5.45

Photometer millivoltmeter reading = .94

°°°0°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	2.85	11	2.80	21	2.35
2	2.85	12	2.82	22	2.30
3	2.90	13	2.84	23	2.30
4	2.80	14	2.68	24	2.20
5	2.30	15	2.25	25	1.82
6	2.30	16	2.10	26	1.50
7	2.65	17	2.60	27	1.75
8	2.80	18	2.86	28	1.92
9	2.77	19	2.76	29	1.95
10	2.82	20	2.68	30	1.90

Average F.C. intensity = 2.45

TABLE XXII

°°°0°°°

Four F-150, S.F., Holophane reflectors, equipped with 150 watts tungsten lamps, in center of room, turned upwards, semi-indirect lighting.

Distance of edge of reflectors from ceiling = 3 ft.

Lamps voltage = 110 volts.

Lamps current = 5.42 amps.

Photometer millivoltmeter reading = .94

°°°0°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	3.90	11	3.55	21	2.10
2	3.65	12	3.15	22	1.98
3	3.35	13	2.65	23	1.80
4	2.80	14	2.25	24	1.50
5	2.20	15	1.80	25	1.25
6	2.05	16	1.48	26	1.03
7	2.50	17	1.90	27	1.18
8	3.00	18	2.25	28	1.35
9	3.48	19	2.65	29	1.50
10	3.80	20	2.89	30	1.52

Average F.C. intensity = 2.35

TABLE XXIII

°°°0°°°

Four F-150, S.F. Holophane reflectors, equipped with 150 watts tungsten lamps, in center of room, turned upwards, semi-indirect lighting.

Distance of edge of reflectors from ceiling = 4 ft.

Lamps voltage = 110 volts.

Lamps current = 5.42 amps.

Photometer millivoltmeter reading = .94

°°°0°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	4.00	11	3.50	21	1.95
2	3.90	12	3.10	22	1.90
3	3.45	13	2.65	23	1.70
4	2.80	14	2.18	24	1.48
5	2.20	15	1.75	25	1.24
6	2.05	16	1.45	26	.98
7	2.60	17	1.85	27	1.15
8	3.15	18	2.25	28	1.30
9	3.55	19	2.58	29	1.38
10	3.95	20	2.68	30	1.45

Average F.C. intensity = 2.37

TABLE XXIV

Four F-150, S.F. Holophane reflectors, equipped with 150 watts tungsten lamps, in center of room, turned upwards, semi-indirect lighting.

Distance of edge of reflectors from the ceiling = 5 ft.

Lamps voltage = 110 volts.

Lamps current = 5.42 amps.

Photometer millivoltmeter reading = .94

* * *

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	4.10	11	3.45	21	1.90
2	3.90	12	3.10	22	1.83
3	3.50	13	2.65	23	1.66
4	2.80	14	2.15	24	1.44
5	2.20	15	1.72	25	1.23
6	2.05	16	1.42	26	.94
7	2.60	17	1.32	27	1.12
8	3.20	18	2.25	38	1.23
9	3.60	19	2.55	29	1.30
10	4.00	20	2.60	30	1.37

Average F.C. intensity = 2.32

TABLE XXV

* * *

Four F-150, S.F. Holophane reflectors, equipped with 150 watts tungsten lamps, Distributed in bays, direct lighting.

Distance of edge of reflectors from ceiling = 3 ft. 9 in.

Lamps voltage = 110 volts.

Lamps current = 5.43 amps.

Photometer millivoltmeter reading = .94

* * *

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	3.10	11	3.10	21	2.50
2	2.90	12	3.85	22	2.80
3	2.90	13	4.50	23	3.10
4	2.75	14	4.00	24	2.70
5	2.20	15	2.80	25	2.18
6	2.55	16	2.65	26	1.57
7	3.27	17	3.75	27	1.88
8	3.60	18	4.30	28	2.00
9	3.35	19	3.70	29	1.93
10	3.10	20	3.10	30	1.85

Average F.C. Intensity = 2.93

TABLE XXVI

°°°0°°°

Four F-150, S.F. Holophane reflectors, equipped with 150 watts tungsten lamps, distributed in bays, direct lighting.

Distance of edge of reflectors from ceiling = 4 ft. 8 in.

Lamps voltage = 110 volts.

Lamps current = 5.42 amps.

Photometer millivoltmeter reading = .94

°°°0°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	2.70	11	3.25	21	2.55
2	2.70	12	4.10	22	3.00
3	2.70	13	4.90	23	3.30
4	2.48	14	4.25	24	2.90
5	2.15	15	2.65	25	2.10
6	2.45	16	2.65	26	1.50
7	3.25	17	4.20	27	1.32
8	3.60	18	5.00	28	2.05
9	3.35	19	4.00	29	1.95
10	3.00	20	3.20	30	1.85

Average F.C. intensity = 2.99

TABLE XXVII

* * *

Four F-150, S.F. Holophane reflectors, equipped with 150 watts tungsten lamps, distributed in bays, direct lighting.

Distance of reflectors from ceiling = 5 ft. 8 in.

Lamps voltage = 110 volts.

Lamps current = 5.42 amps.

Photometer millivoltmeter reading. = .94

* * *

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	2.75	11	3.25	21	2.40
2	2.90	12	4.55	22	2.85
3	3.00	13	6.60	23	3.35
4	2.60	14	5.20	24	2.90
5	2.30	15	3.10	25	2.05
6	2.60	16	2.90	26	1.50
7	3.60	17	4.55	27	1.60
8	4.00	18	5.90	28	1.85
9	3.45	19	4.20	29	1.77
10	2.90	20	3.00	30	1.72

Average F.C. intensity = 3.17

TABLE XXVIII

Four F-150, S.F. Holophane reflectors, equipped with 150 watts tungsten lamps. Distributed in bays, turned upwards.

Distance of edge of reflectors from ceiling = 2 ft.

Lamps voltage = 110 volts

Lamps current = 5.45 amps.

Photometer millivoltmeter reading =.94

* * *

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	2.30	11	2.20	21	1.36
2	2.30	12	2.10	22	1.82
3	2.15	13	1.92	23	1.76
4	1.94	14	1.79	24	1.65
5	1.73	15	1.62	25	1.46
6	1.74	16	1.51	26	1.25
7	1.95	17	1.69	27	1.35
8	2.10	18	1.80	28	1.49
9	2.25	19	2.00	29	1.50
10	2.30	20	2.02	30	1.50

Average F.C. intensity = 1.83

-TABLE-XXIX-

°°°0°°°

Four F-150, S.F. Holophane reflectors, equipped with 150 watts tungsten lamps, distributed in bays, turned upwards.

Distance of edge of reflectors from ceiling = 3 ft.

Lamps voltage = 110 volts.

Lzmps current = 5.45 amps.

Photometer millivoltmeter reading = .94

°°°0°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	2.30	11	2.20	21	1.81
2	2.20	12	2.12	22	1.79
3	2.17	13	1.85	23	1.74
4	1.98	14	1.79	24	1.61
5	1.73	15	1.65	25	1.45
6	1.77	16	1.55	26	1.20
7	1.96	17	1.76	27	1.35
8	2.10	18	1.78	28	1.52
9	2.22	19	2.00	29	1.54
10	2.30	20	2.07	30	1.54

Average F.C. Intensity = 1.83

TABLE XXX

°°°0°°°

Four F-150, S.F. Holophane reflectors, equipped with 150 watts tungsten lamps, distributed in bays, turned upwards.

Distance of edge of reflectors from ceiling = 4 ft.

Lamps voltage = 110 volts.

Lamps current = 5.45 amps.

Photometer millivoltmeter reading = .94

°°°0°°°

Sta.	F.C. Int.	Sta.	F.C. Int.	Sta.	F.C. Int.
1	2.25	11	2.18	21	2.00
2	2.20	12	2.18	22	1.70
3	2.10	13	1.82	23	1.69
4	1.83	14	1.92	24	1.59
5	1.76	15	1.66	25	1.43
6	1.75	16	1.52	26	1.21
7	1.99	17	1.72	27	1.34
8	2.10	18	1.74	28	1.50
9	2.21	19	2.03	29	1.52
10	2.28	20	2.13	30	1.53

Average F.C. intensity = 1.83

TABLE XXXI

Operating characteristics of four E-100 Natioaal X Ray reflectors, equipped with 150 watts tungsten lamps, placed in a room 27.5 ft. lomg, 23 ft. wide, and 14.5 ft. high.

	Distance of reflectors from ceiling	Mean F.C. intensity	Effective lumens	Generated lumens	$\text{Eff.} = \frac{\text{Effec. lumens}}{\text{Gen. lumens}}$	Effective lum. per watt
Reflectors on center fixture	2	1.90	1200	4405	.278	2.00
	3	1.92	1215	4405	.276	2.02
	4	1.91	1207	4405	.275	2.01
	5	1.80	1140	4405	.258	1.90
Reflectors distributed in four bays.	2	1.88	1190	4405	.270	1.98
	3	1.87	1188	4405	.270	1.97
	4	1.86	1186	4405	.270	1.96

TABLE XXXII

Operating characteristics of four #3445 Alba reflectors equipped with 150 watts tungsten lamps, placed in a room 27.5 ft.long, 23 ft. wide, and 14.5 ft. high.

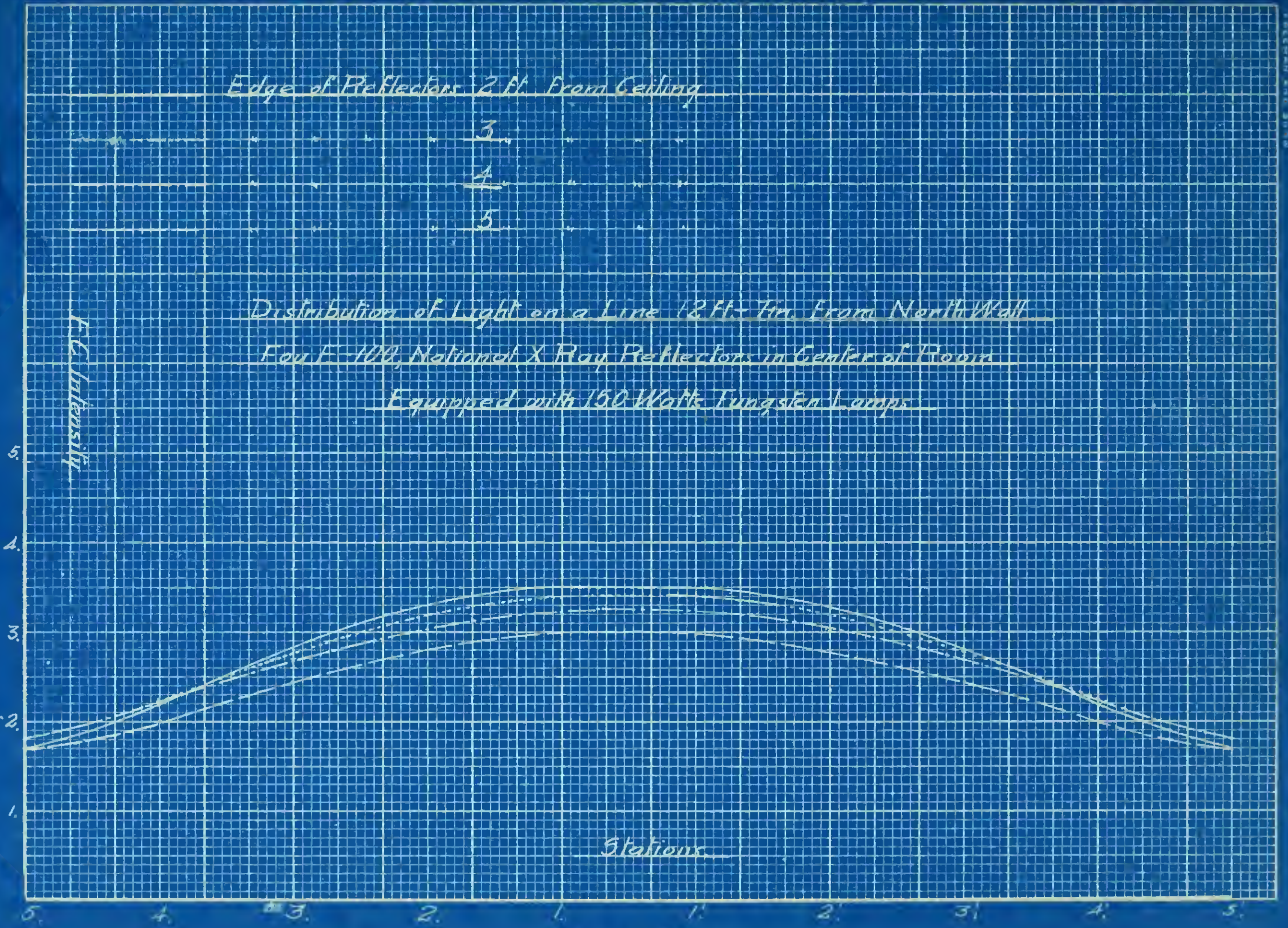
	Dis. of reflectors from ceiling in ft.	Mean F.C. intensity	Effective lumens	Generated lumens	Eff. = $\frac{\text{Effec. lum.}}{\text{Gen. lum.}}$	Effec. lum./watt
Reflectors in center fixture turned upwards	3	2.70	1710	4405	.387	2.85
	4	2.76	1740	4405	.395	2.92
	5	2.83	1790	4405	.406	2.98
Reflectors distributed in four bays direct lighting	3.75	2.83	1790	4405	.406	2.98
	4.75	2.97	1880	4405	.426	3.14
	5.75	3.04	1920	4405	.436	3.20
Reflectors distributed in four bays turned upwards	2.	2.33	1470	4405	.334	2.45
	3	2.37	1500	4405	.340	2.50
	4	2.45	1550	4405	.352	2.58

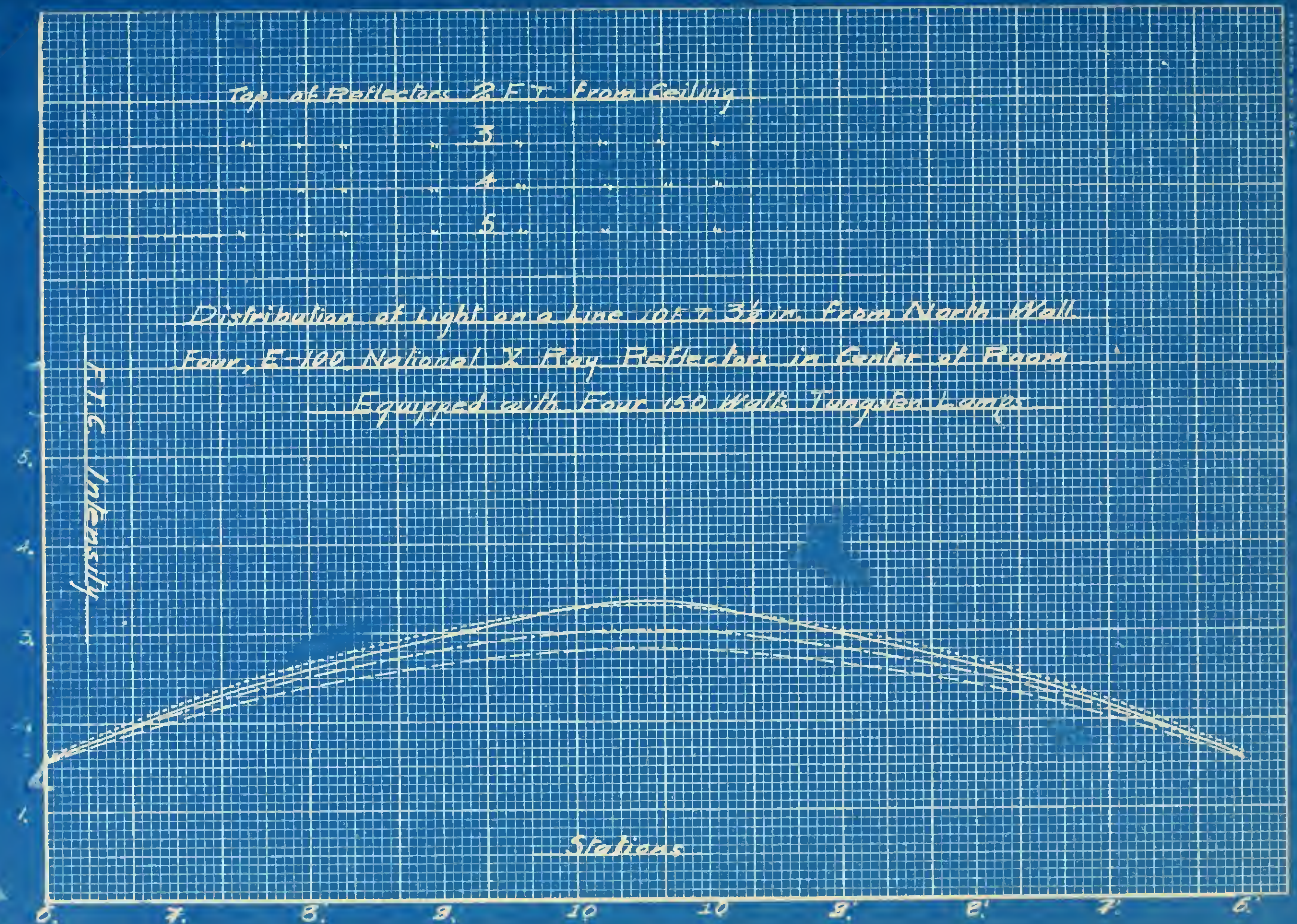
TABLE XXXIII

°°°0°°°

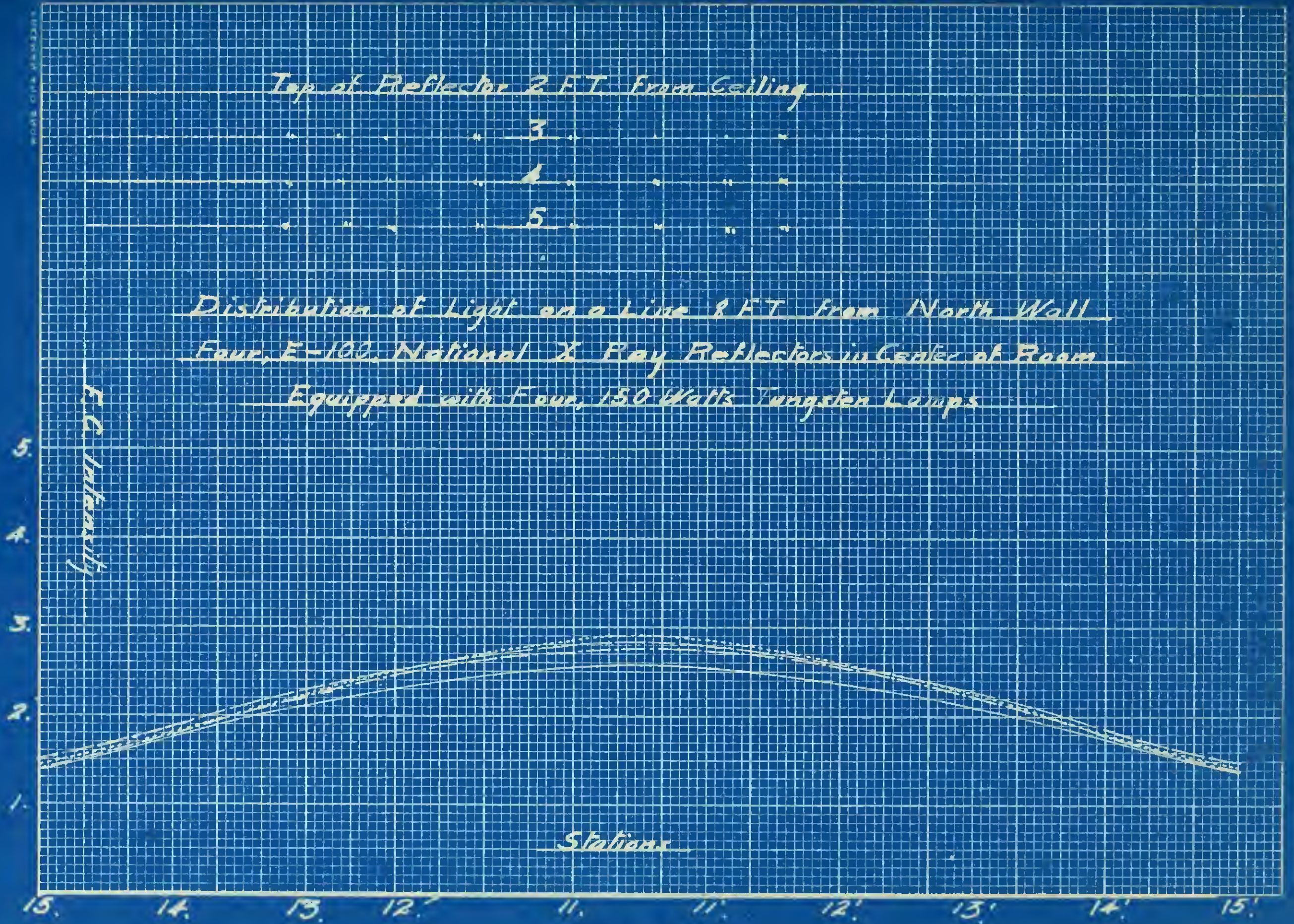
Operating characteristics of four F-150, S.F. Holophane reflectors, equipped with 150 watts tungsten lamps, placed in a room 27.5 ft. long, 23 ft, wide, and 14.5 ft. high.

	Distance of reflectors from ceiling, in ft.	Mean F.C. intensity	Effective lumens	Generated lumens	Eff. = Effec. lumens / Gen. lumens	Effec. lumens per watt
Reflectors on	3	2.35	1485	4405	.337	2.47
center fixture	4	2.37	1500	4405	.340	2.50
turned upwards	5	2.32	1468	4405	.333	2.44
Reflectors	3.75	2.93	1358	4405	.420	3.08
distributed in four bays	4.75	2.99	1390	4405	.429	3.15
direct lighting	5.75	3.17	2000	4405	.453	3.33
Reflectors	2	1.83	1165	4405	.263	1.93
distributed in four bays	3	1.83	1165	4405	.263	1.93
turned upwards	4	1.83	1165	4405	.263	1.93


FREEMAN AND SONS
Edge of Reflectors 2 Ft. From Ceiling
3
4
5
Distribution of Light on a Line 12 Ft. 7in. From North Wall
Four F 100, National X Ray Reflectors in Center of Room
Equipped with 150 Watt Tungsten Lamps
F.C. Intensity
5.
4.
3.
2.
1.
Stations
5.
4.
3.
2.
1.
1.'
2.'
3.'
4.'
5.'


Top of Reflectors 2 FT. From Ceiling
3
4
5
Distribution of Light on a Line 10 FT. 3½ in. From North Wall
Four, E-100 National X Ray Reflectors in Center of Room
Equipped with Four 150 Watts Tungsten Lamps
F.T.C. Intensity
1.
2.
3.
4.
5.
Stations
6.
7.
8.
9.
10
10
9.
8.
7.
6.

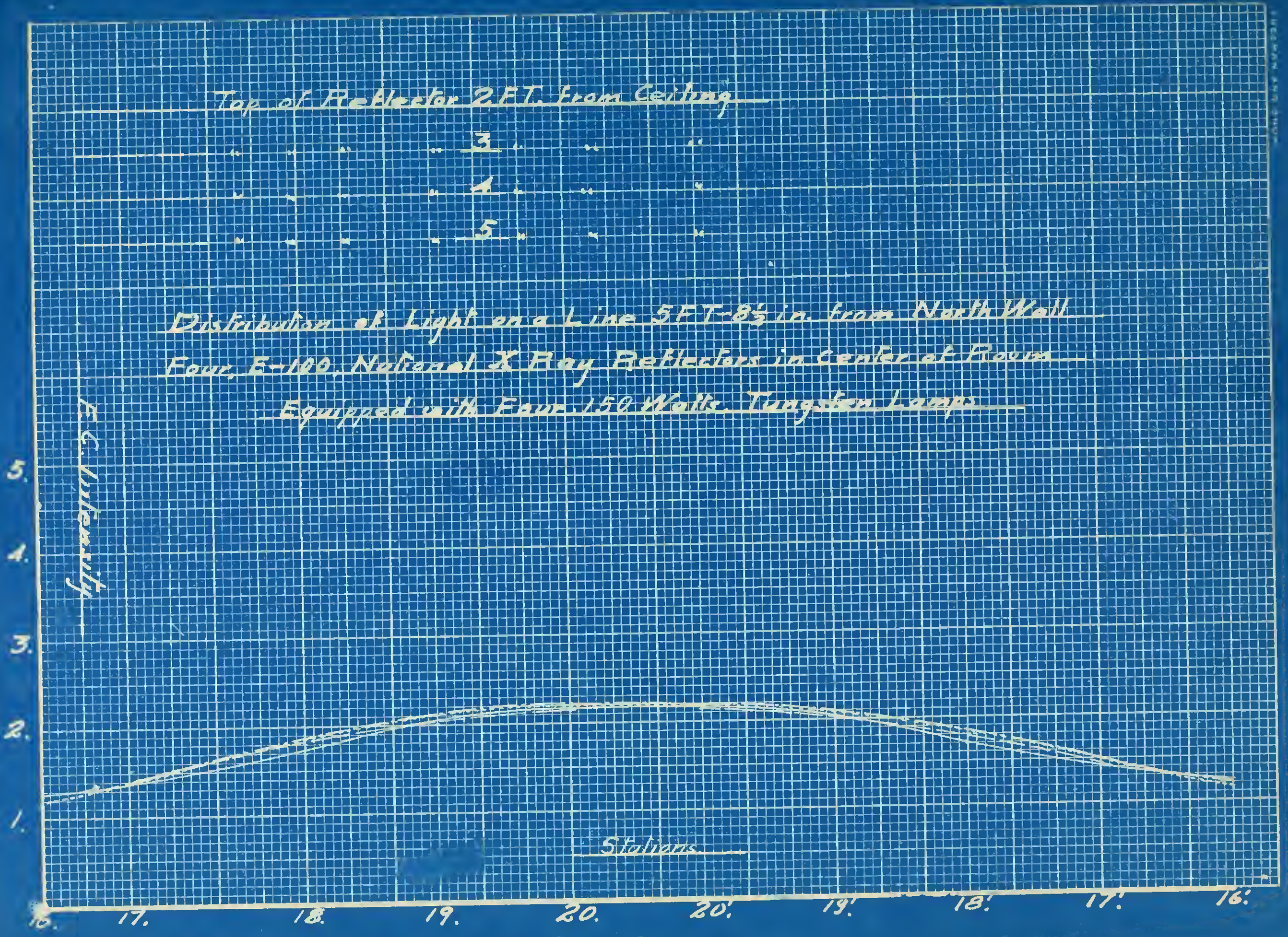
Crouch Fig.



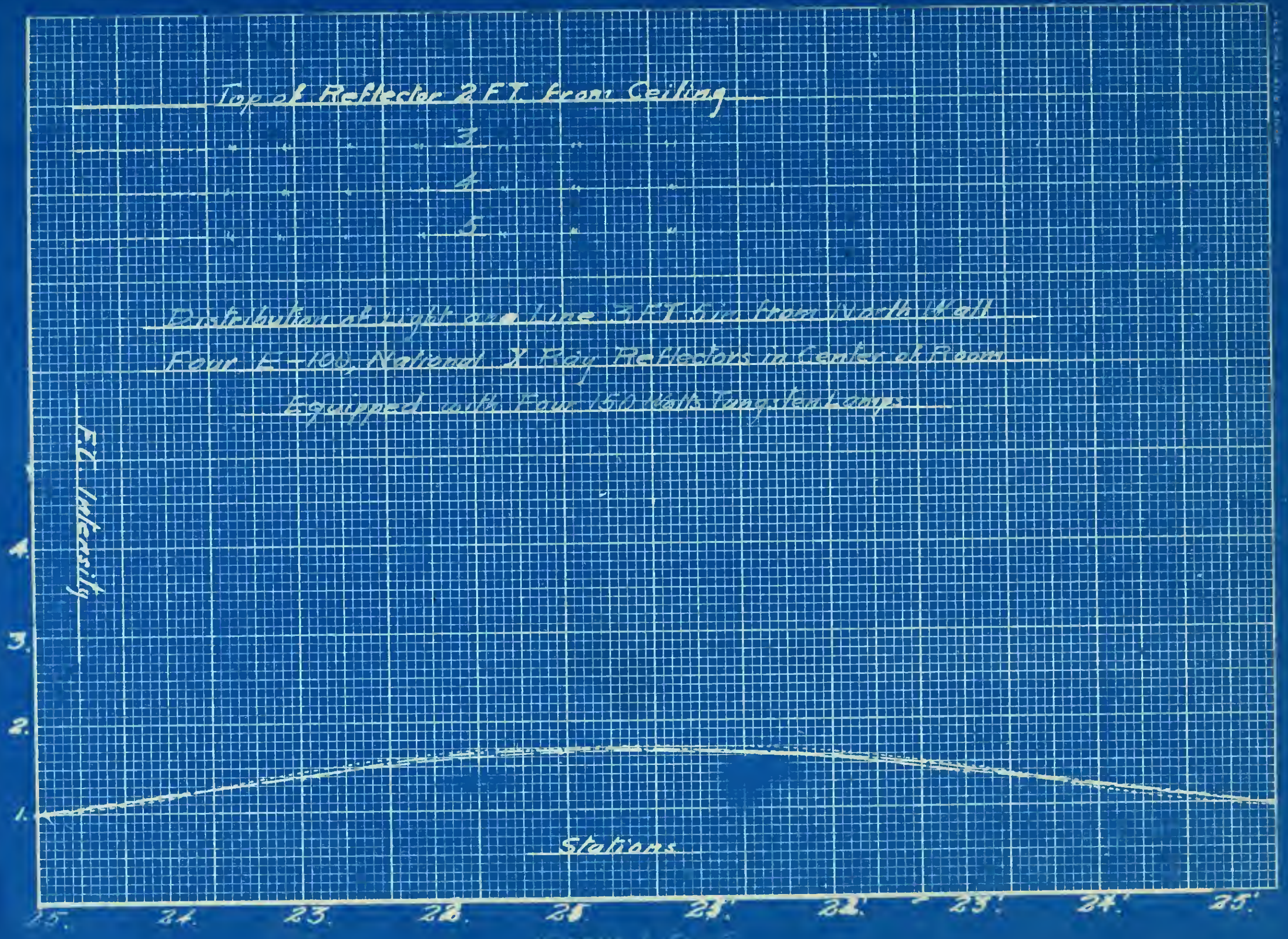
Distribution of Light on a Line 8 FT. from North Wall

Four, E-100, National X Ray Reflectors in Center of Room

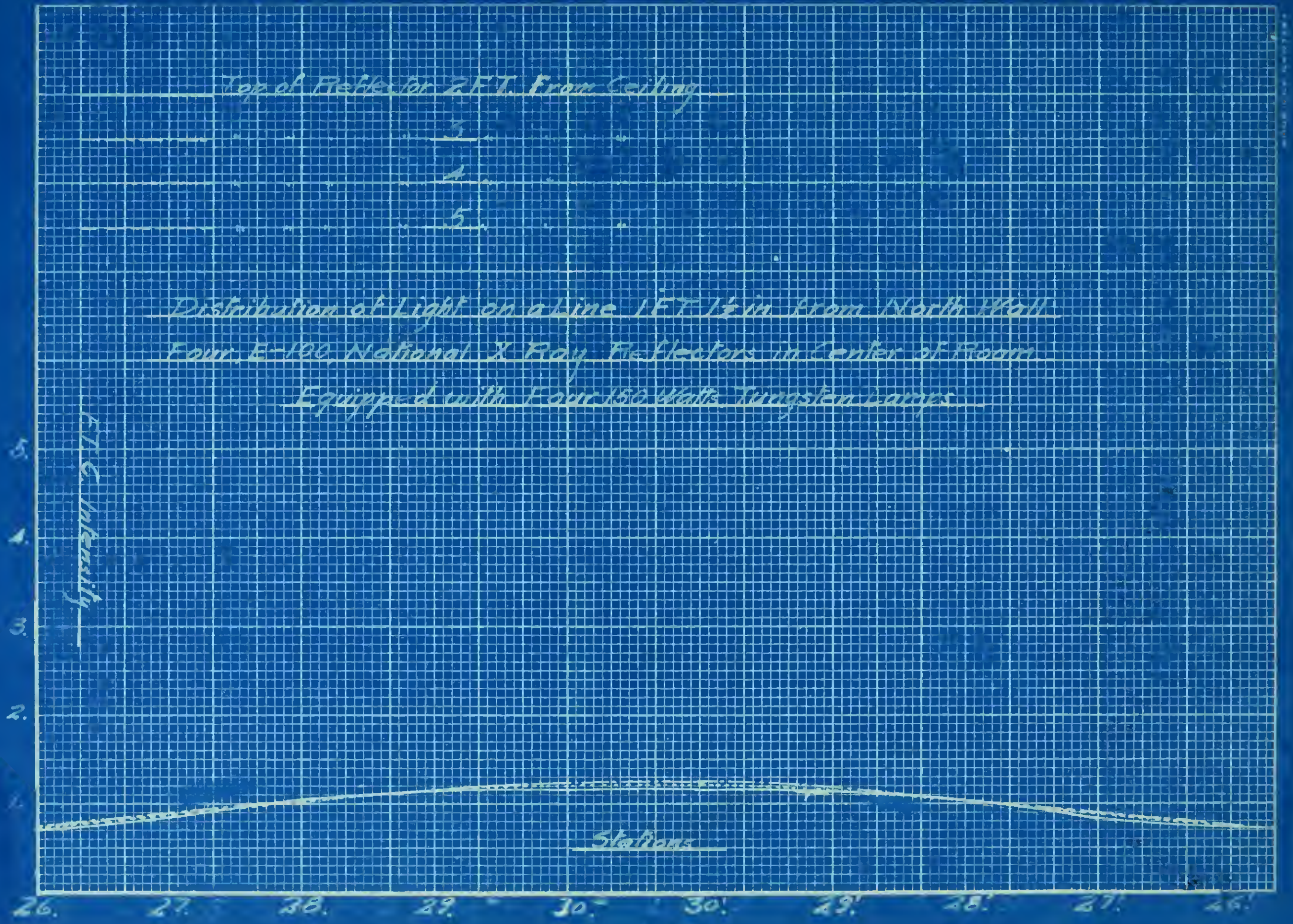
Equipped with Four, 150 Watts Tungsten Lamps


Top of Reflector 2 FT. from Ceiling
3
4
5
Distribution of Light on a Line 5 FT-8½ in. from North Wall
Four, E-100, National X Ray Reflectors in Center of Room
Equipped with Four 150 Watts Tungsten Lamps
E.C. Intensity
5.
4.
3.
2.
1.
16.
17.
18.
19.
20.
20'.
19'.
18'.
17'.
16'.
Stations

Group 1, Fig. 7


Top of Reflector 2 FT. From Ceiling
3
4
5
Distribution of Light on a Line 3 FT. 5 in. From North Wall
Four E-100, National X Ray Reflectors in Center of Room
Equipped with Four 150 Watt Tungsten Lamps
F.C. Intensity
4.
3.
2.
1.
Stations
25.
24.
23.
22.
21.
21'.
22'.
23'.
24'.
25'.

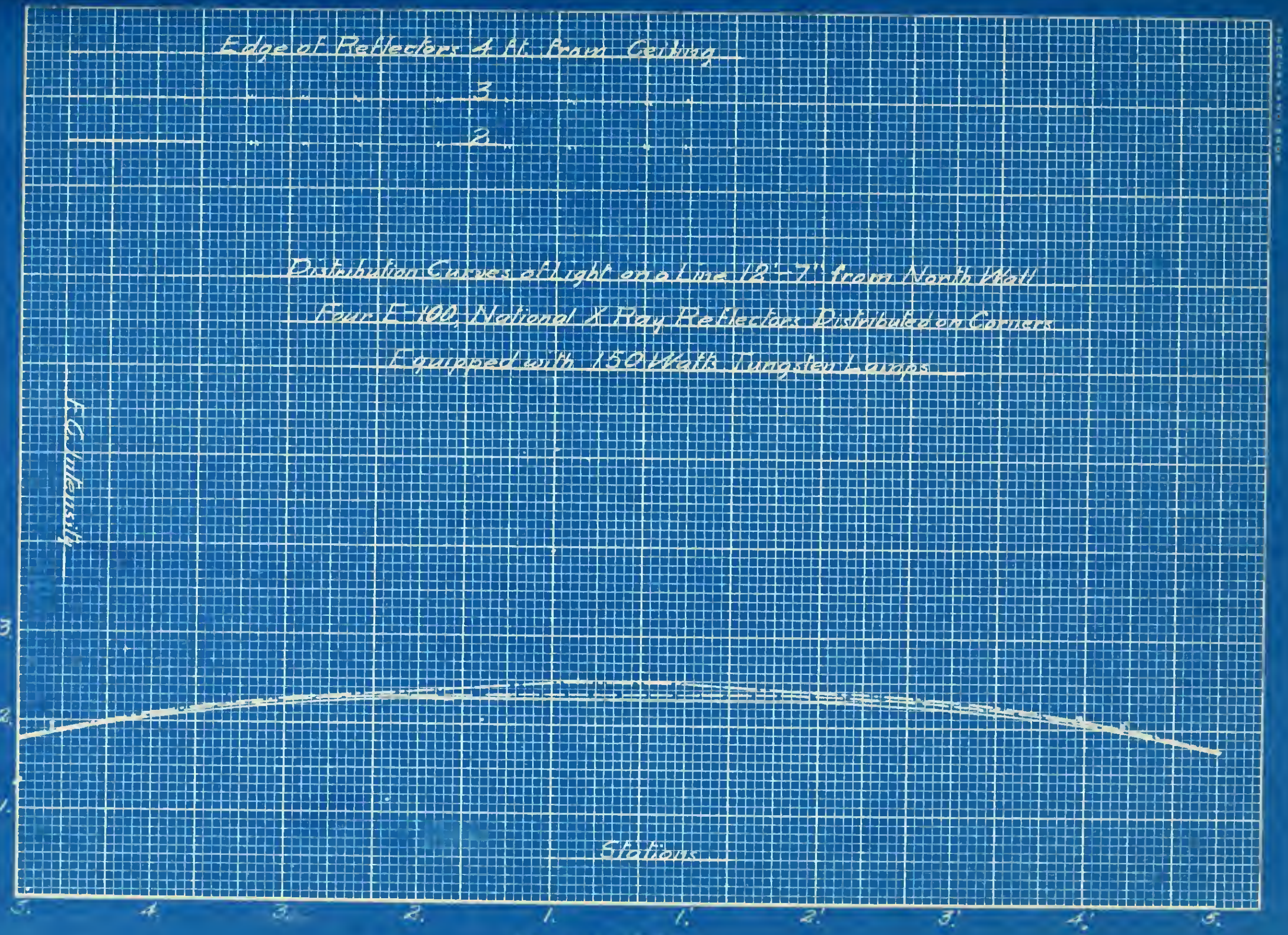
Group 1, Fig. 3



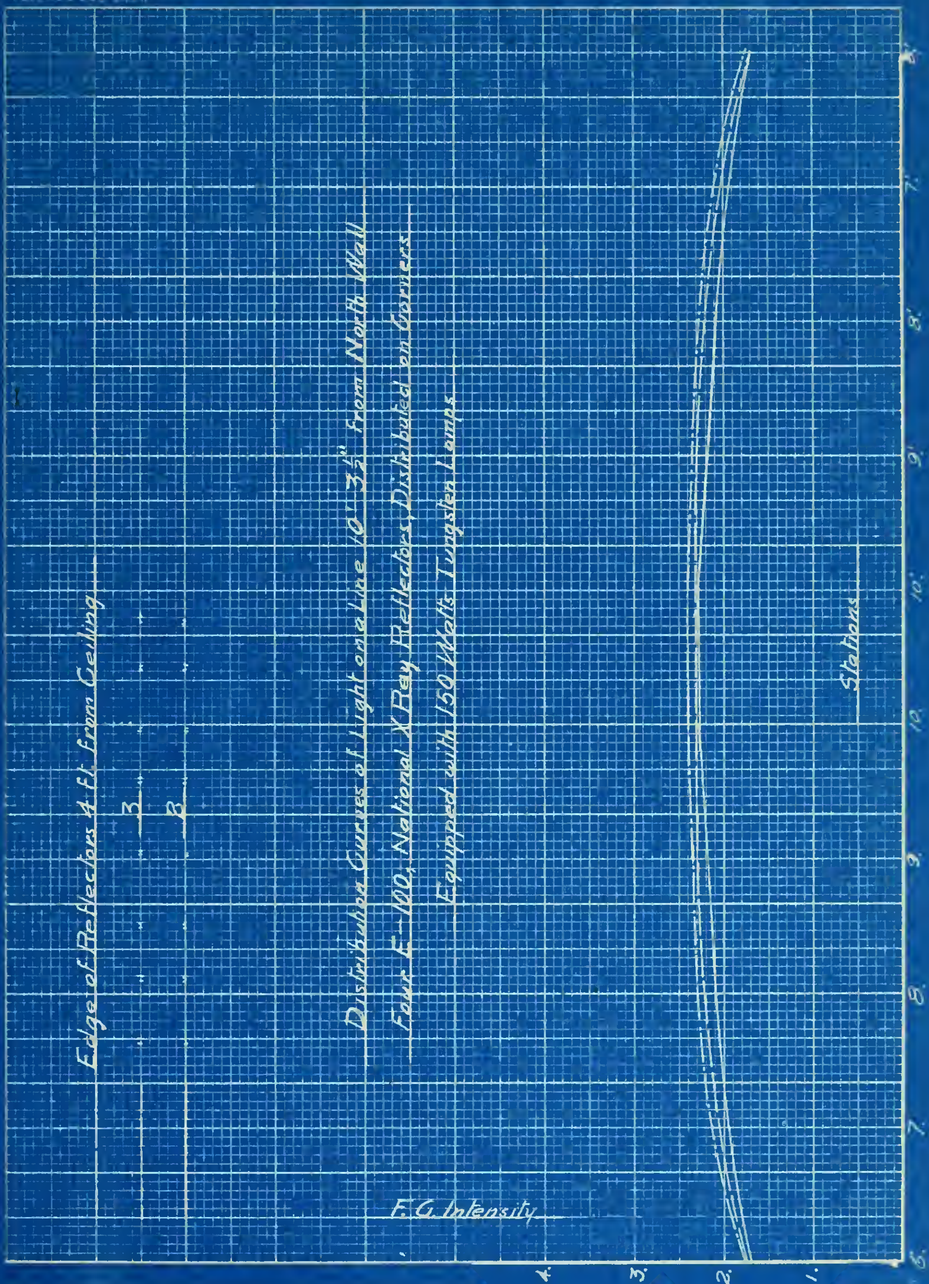
Distribution of Light on a Line 1 FT. 1½ in. from North Wall

Four E-100 National X Ray Reflectors in Center of Room

Equipped with Four 150 Watts Tungsten Lamps



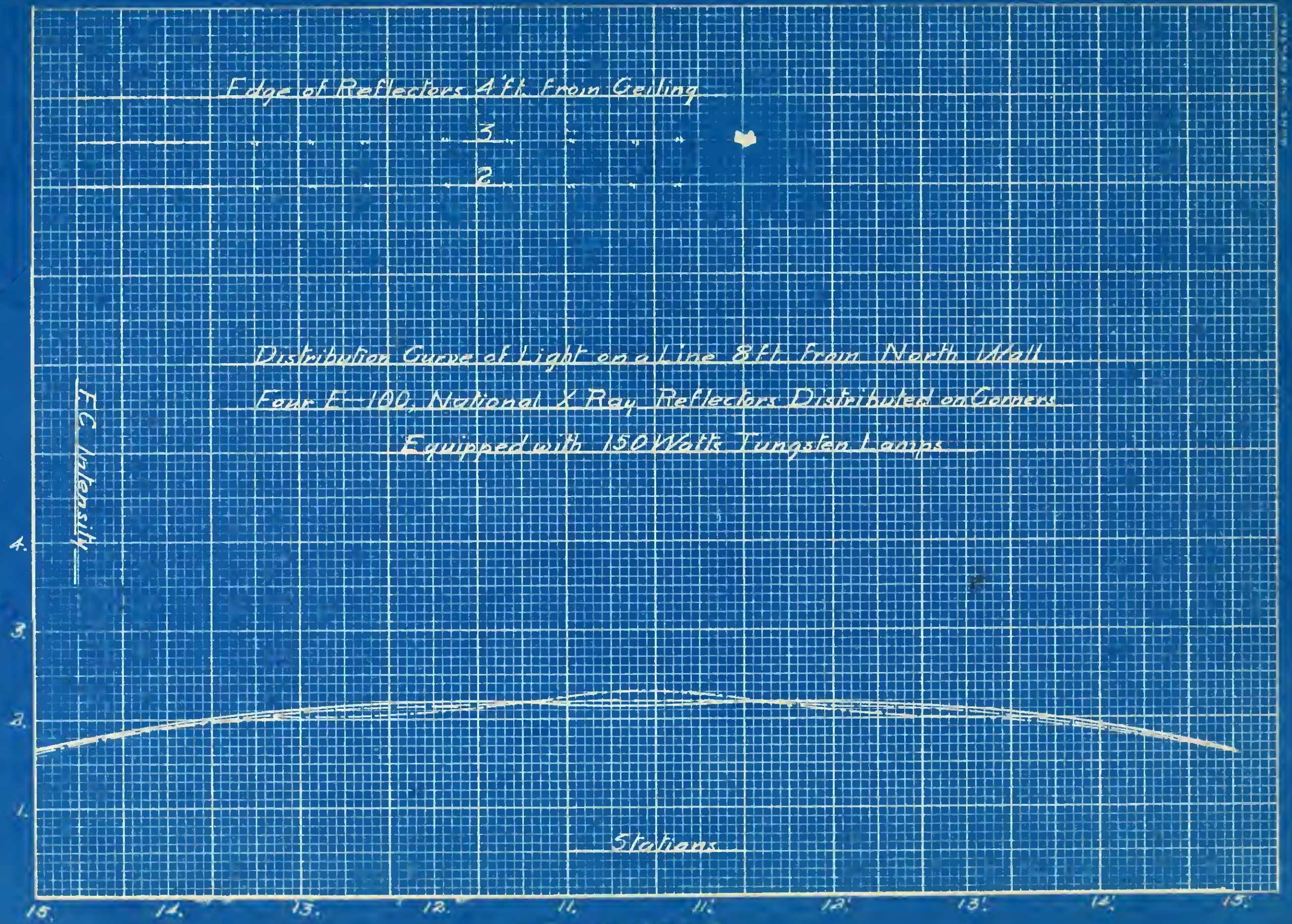
Group II Fig. 7



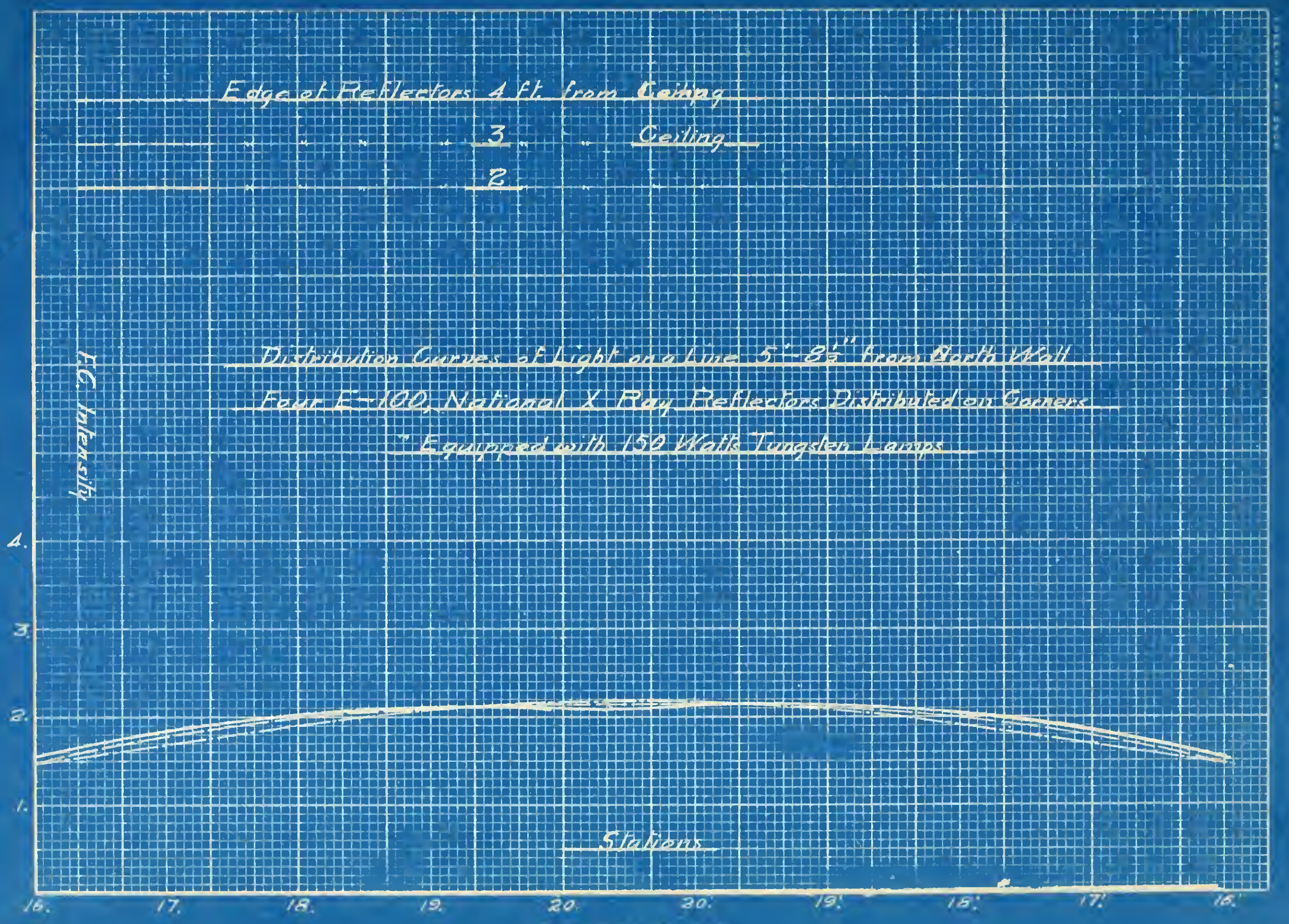
Distribution Curves of Light on a Line 10' 3½" From North Wall

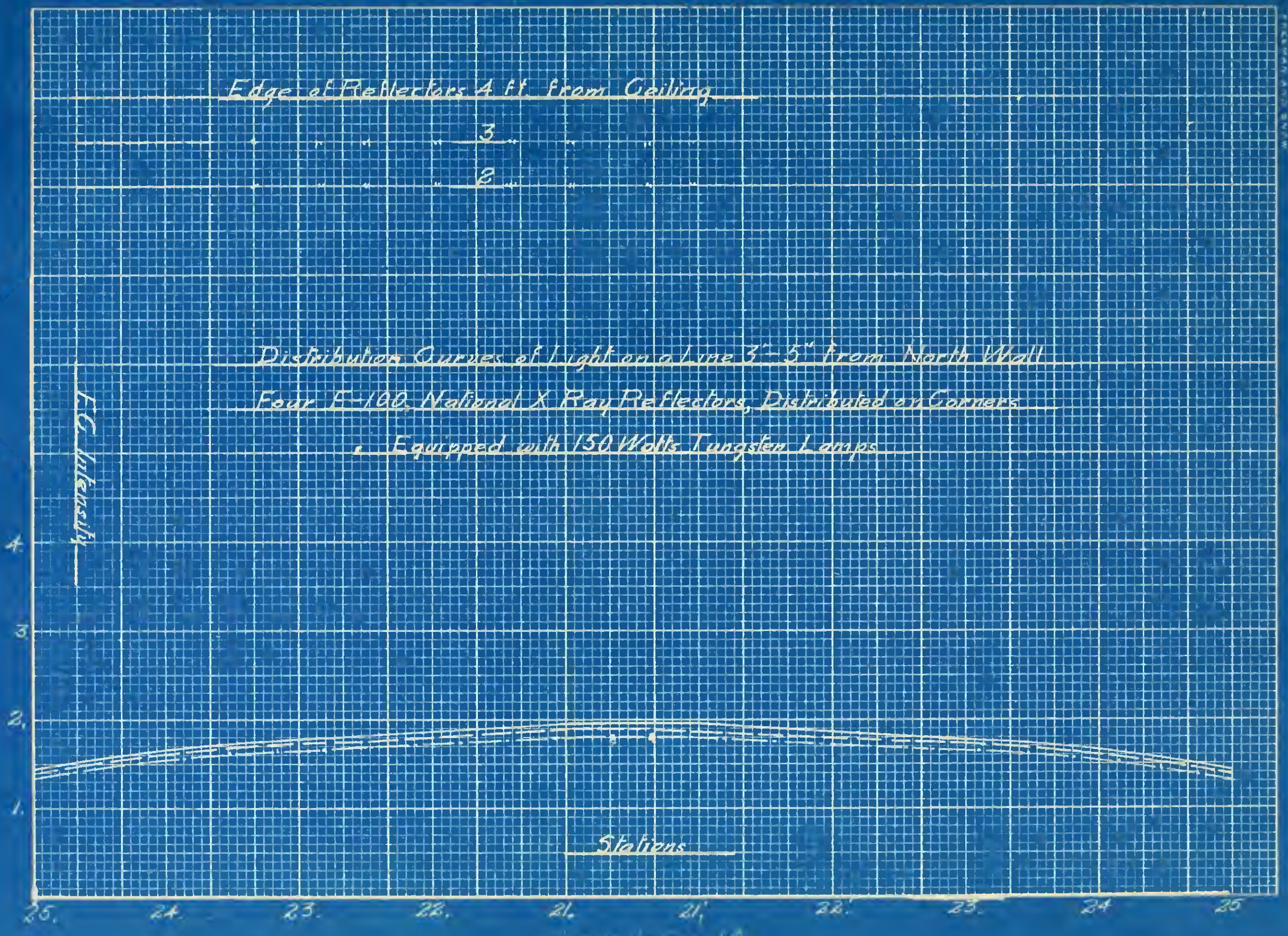
Four E-100, National X Ray Reflectors, Distributed on Corners

Equipped with 150 Watts Tungsten Lamps



Group II, Fig 2.

Edge of Reflectors 4 Ft. from Ceiling
3
Ceiling
2
Distribution Curves of Light on a Line 5'-8½" from North Wall
Four E-100, National X Ray Reflectors Distributed on Corners
" Equipped with 150 Watt Tungsten Lamps
F.C. Intensity
4.
3.
2.
1.
Stations
16.
17.
18.
19.
20.
20.'
19.'
18.'
17.'
16.'

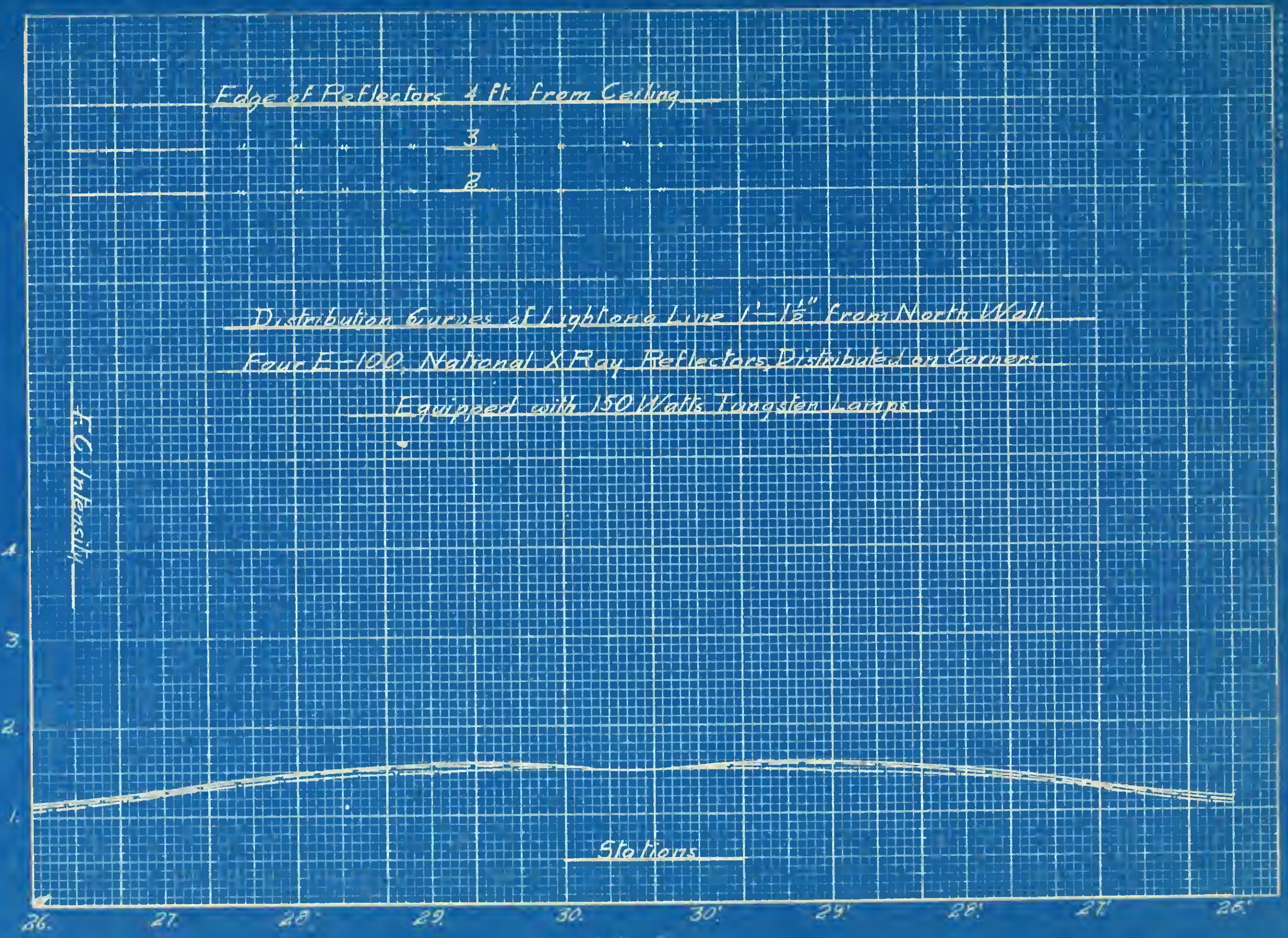

Distribution Curves of Light on a Line 3'-5" from North Wall

Four E-100, National X Ray Reflectors, Distributed on Corners

Equipped with 150 Watts Tungsten Lamps

Edge of Reflectors 4 ft. from Ceiling

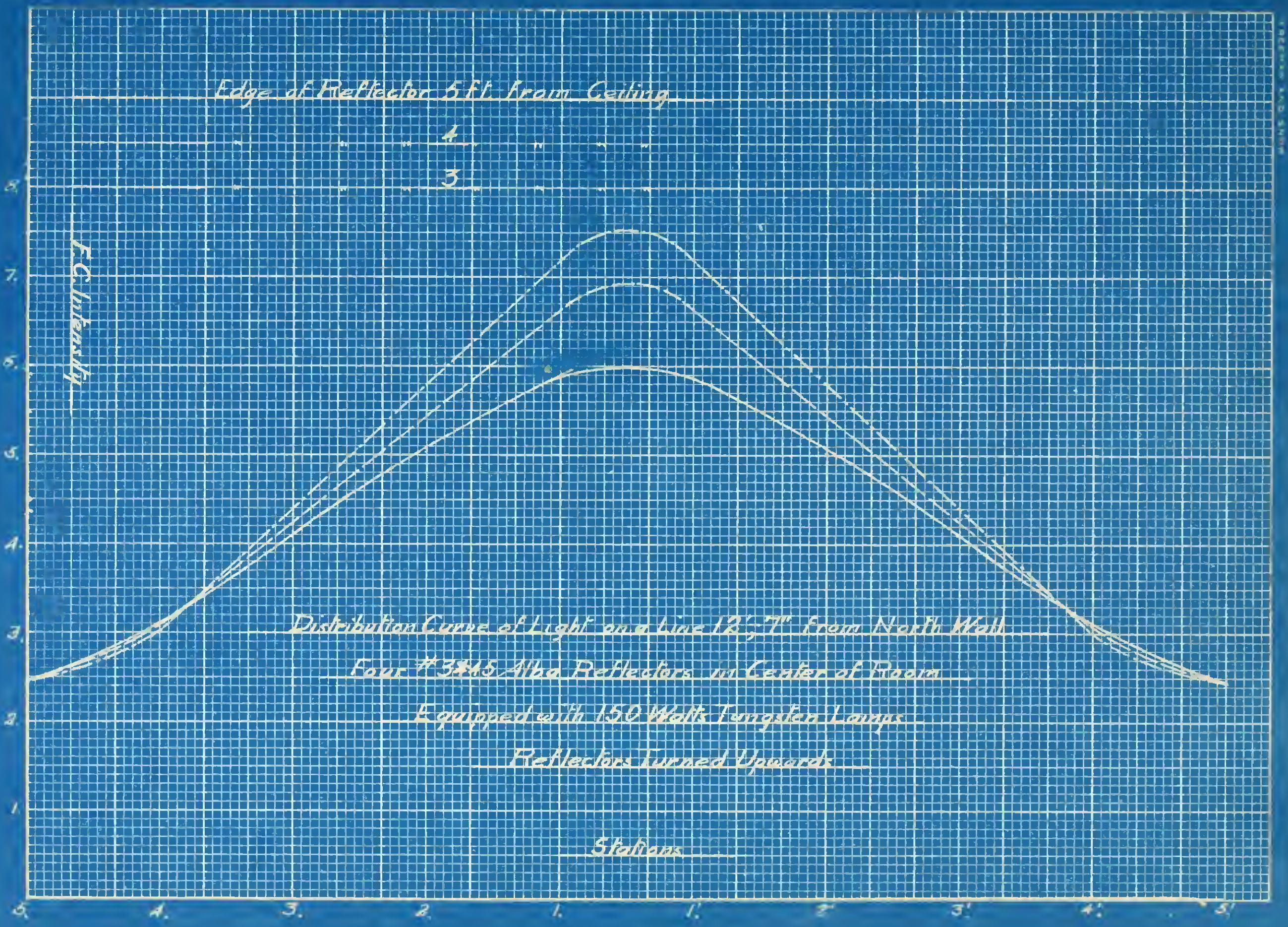
[illegible] 12

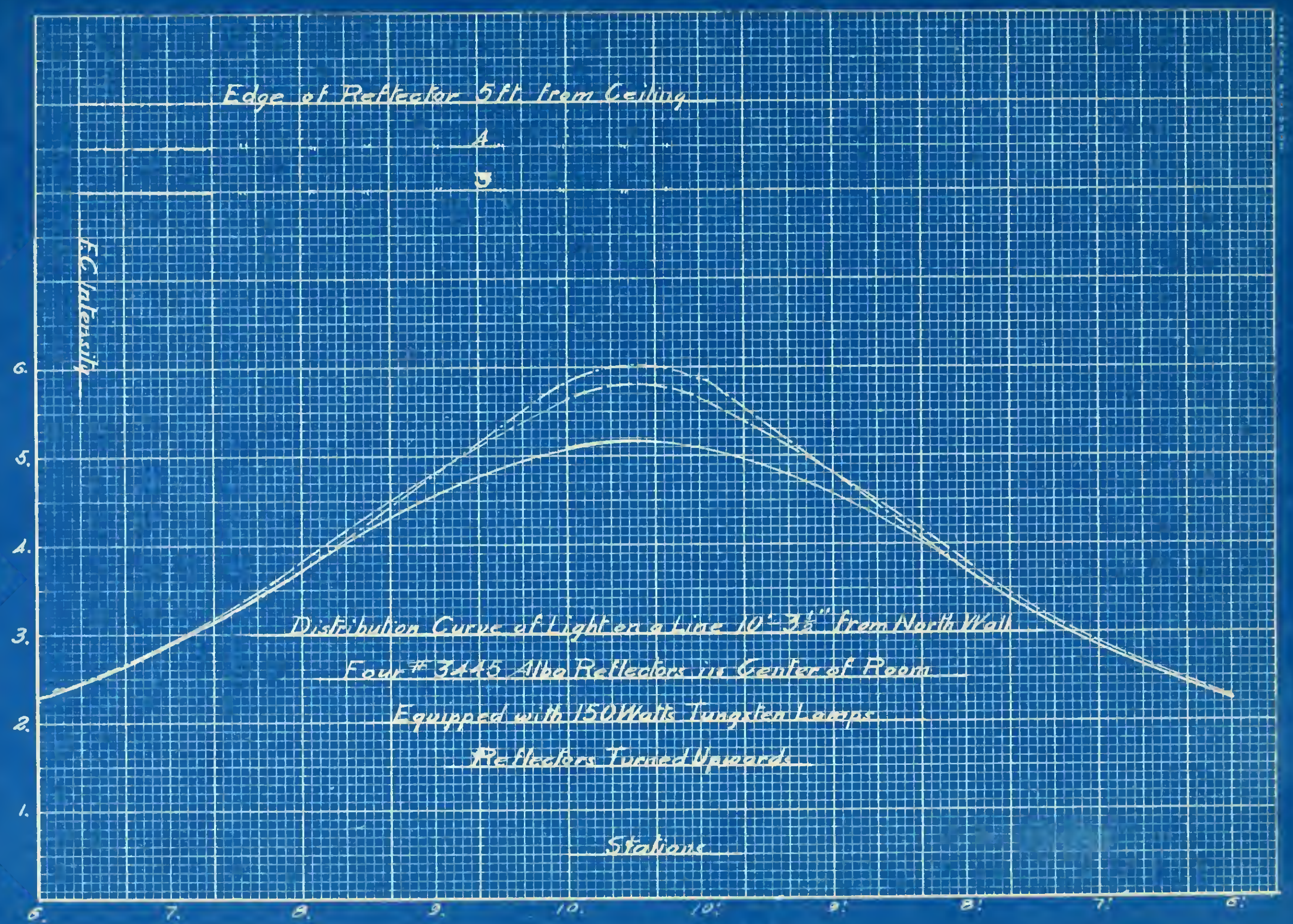


Distribution Curves of Lighting a Line 1'–1½" from North Wall

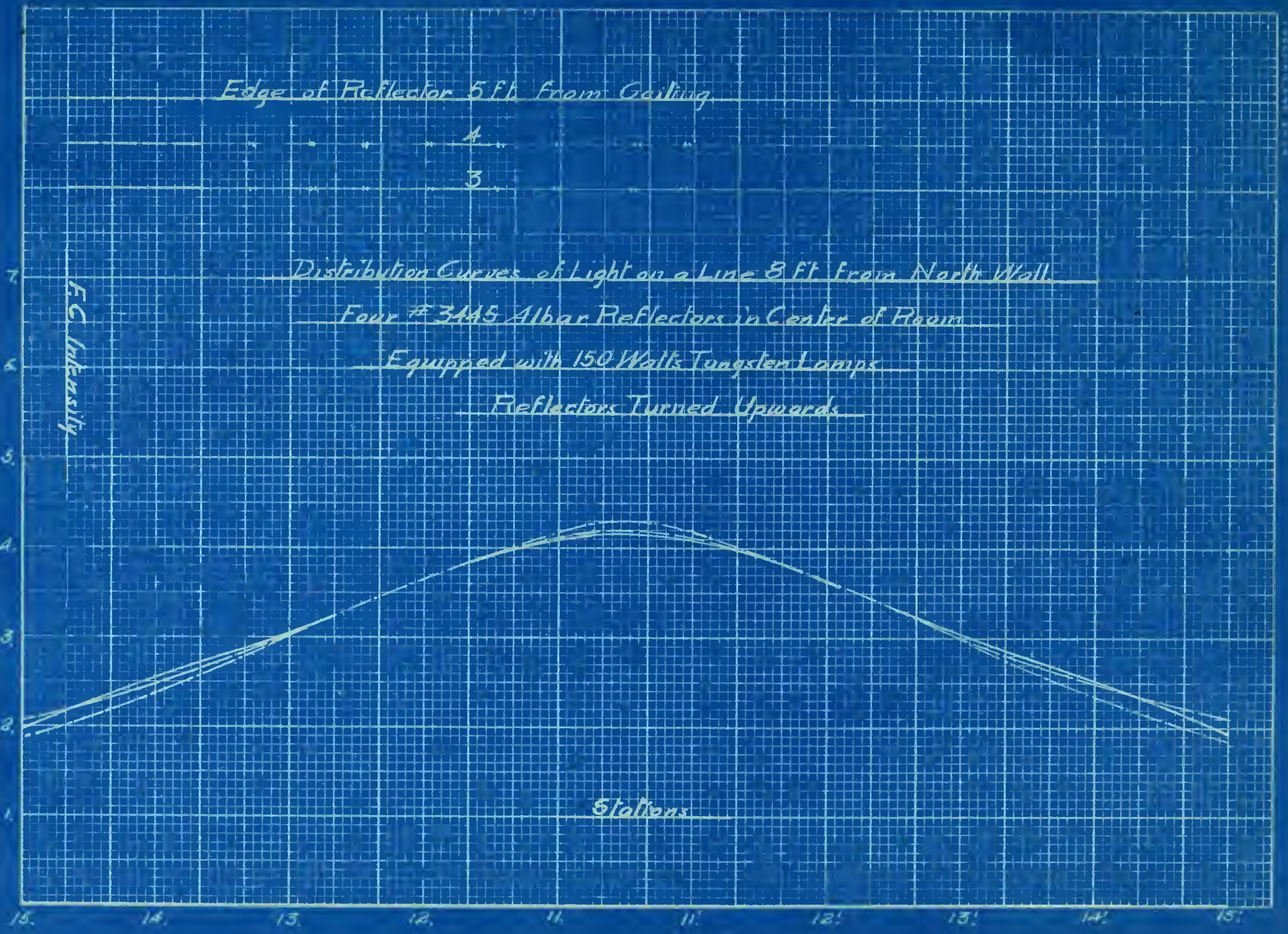
Four E-100, National X Ray Reflectors, Distributed on Corners

Equipped with 150 Watts Tungsten Lamps


Edge of Reflector 5 Ft. from Ceiling
4
3
F.C. Intensity
8.
7.
6.
5.
4.
3.
2.
1.
Distribution Curve of Light on a Line 12'-7" from North Wall
Four #3445 Alba Reflectors in Center of Room
Equipped with 150 Watts Tungsten Lamps
Reflectors Turned Upwards
Stations
5.
4.
3.
2.
1.
1'.
2'.
3'.
4'.
5'.


Edge of Reflector 5 ft from Ceiling
A
B
F.C Intensity
6.
5.
4.
3.
2.
1.
Distribution Curve of Light on a Line 10'-3½" from North Wall
Four # 3445 Alba Reflectors in Center of Room
Equipped with 150 Watts Tungsten Lamps
Reflectors Turned Upwards
Stations
6.
7.
8.
9.
10.
10'.
9'.
8'.
7'.
6'.

[illegible] Fig. 16



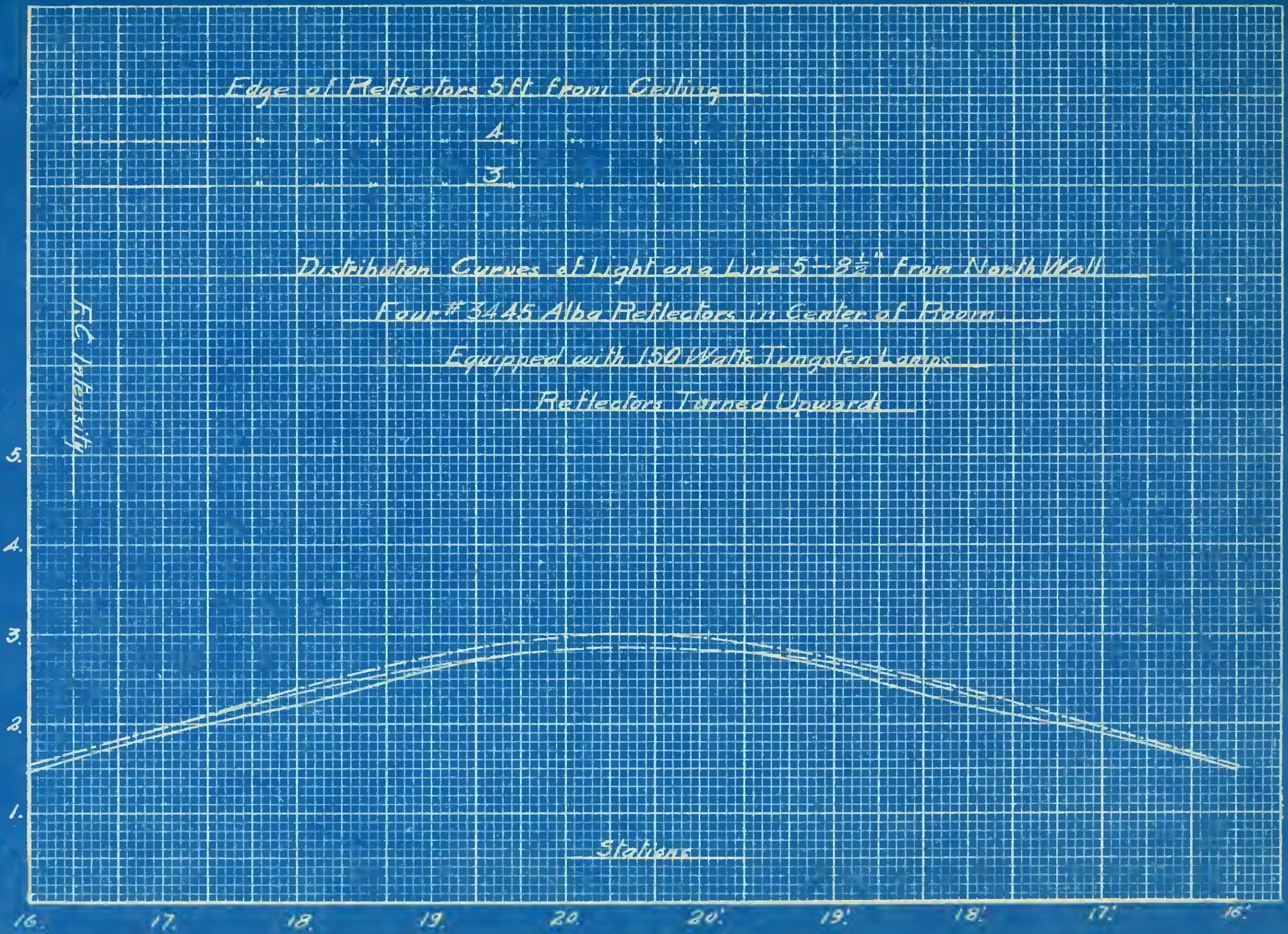
Distribution Curves of Light on a Line 8 Ft From North Wall.

Four # 3445 Albar Reflectors in Center of Room

Equipped with 150 Watts Tungsten Lamps

Reflectors Turned Upwards

FREEMAN AND SNOW



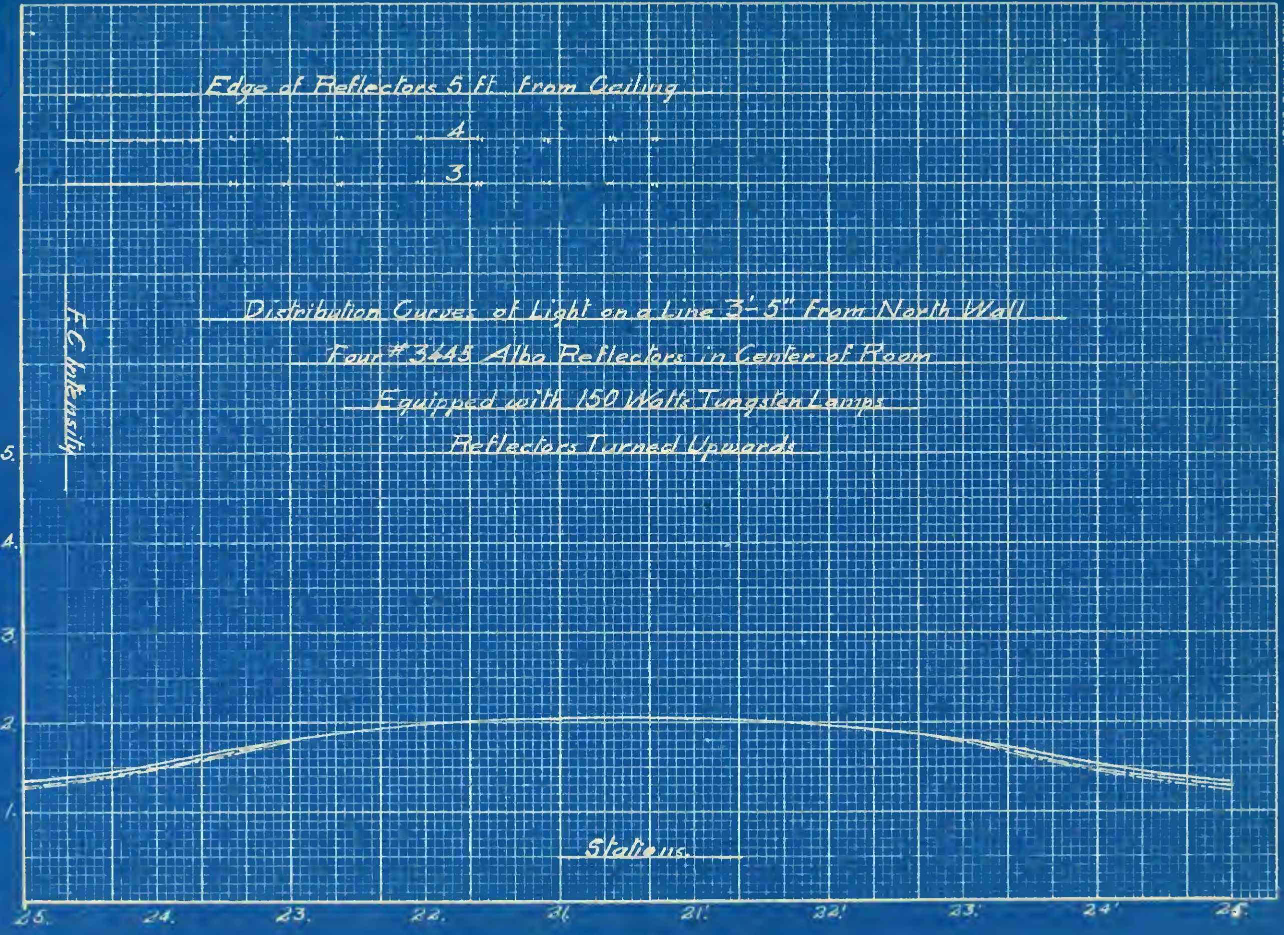
Distribution Curves of Light on a Line 5-8½" From North Wall

Four # 3445 Alba Reflectors in Center of Room

Equipped with 150 Watts Tungsten Lamps

Reflectors Turned Upwards

FREEMAN AND SNOW



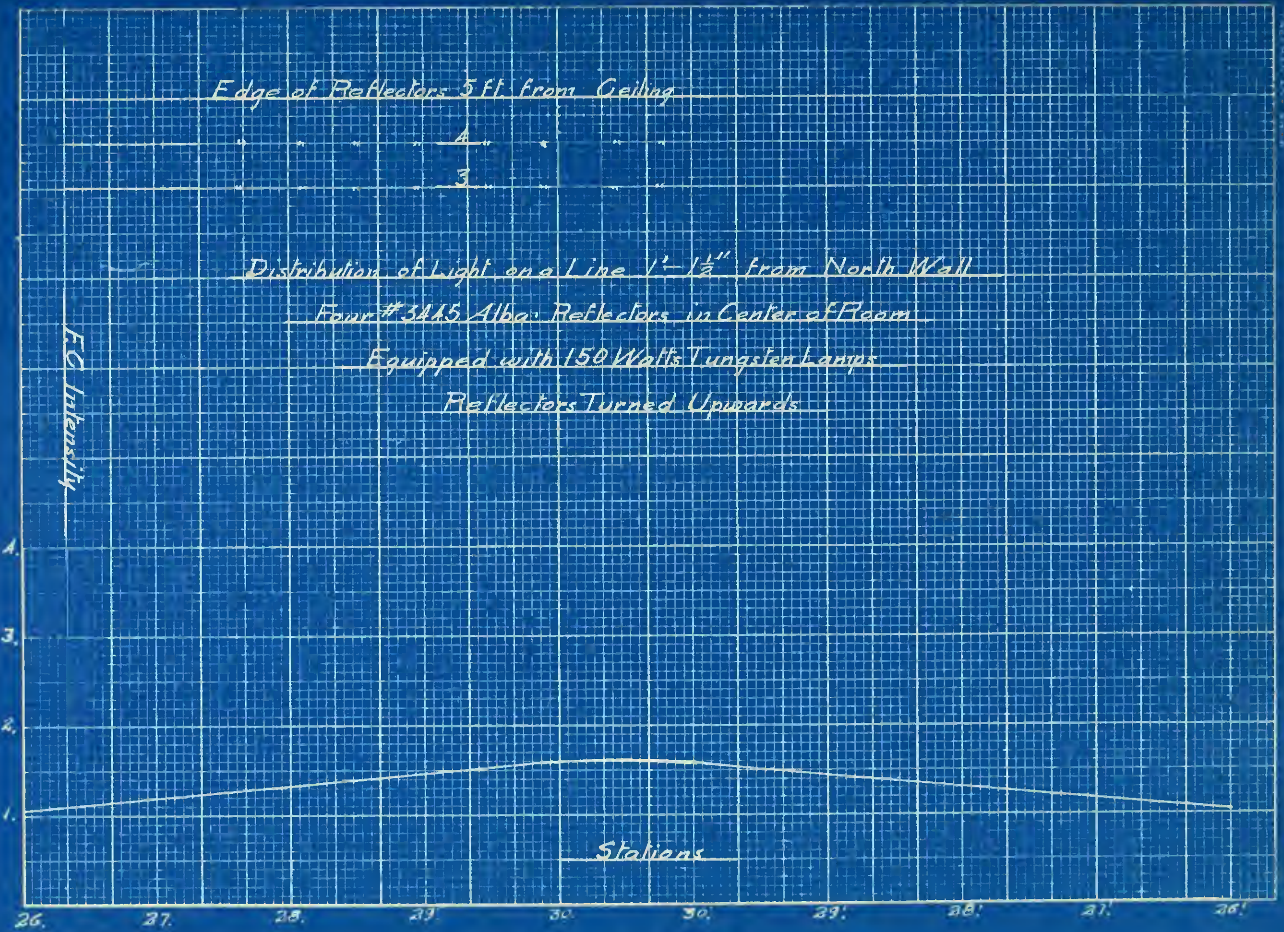
Edge of Reflectors 5 Ft. From Ceiling

Distribution Curves of Light on a Line 3'-5" From North Wall

Four #3445 Alba Reflectors in Center of Room

Equipped with 150 Watts Tungsten Lamps

Reflectors Turned Upwards



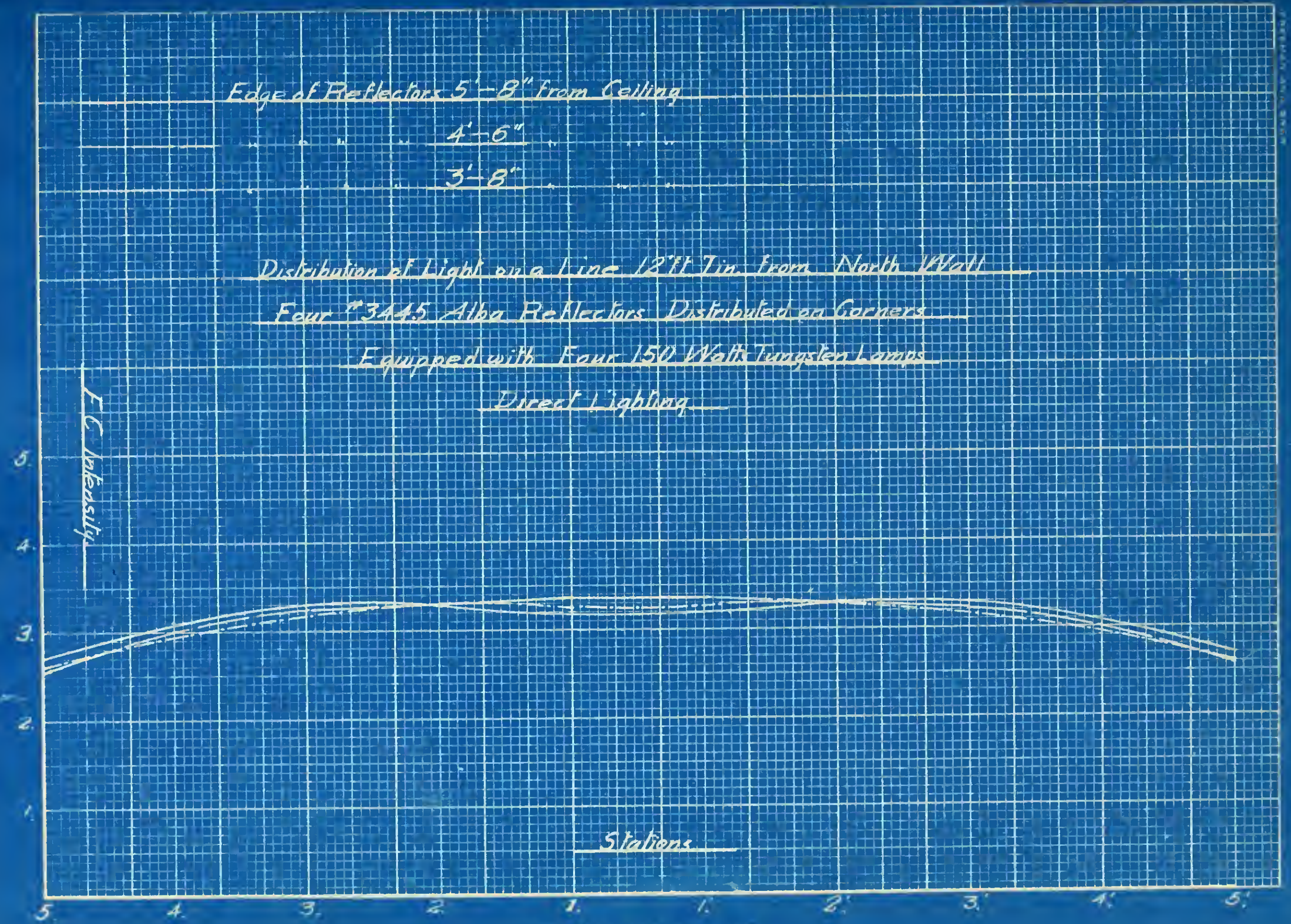
Distribution of Light on a Line 1'-1½" from North Wall

Four #3445 Alba Reflectors in Center of Room

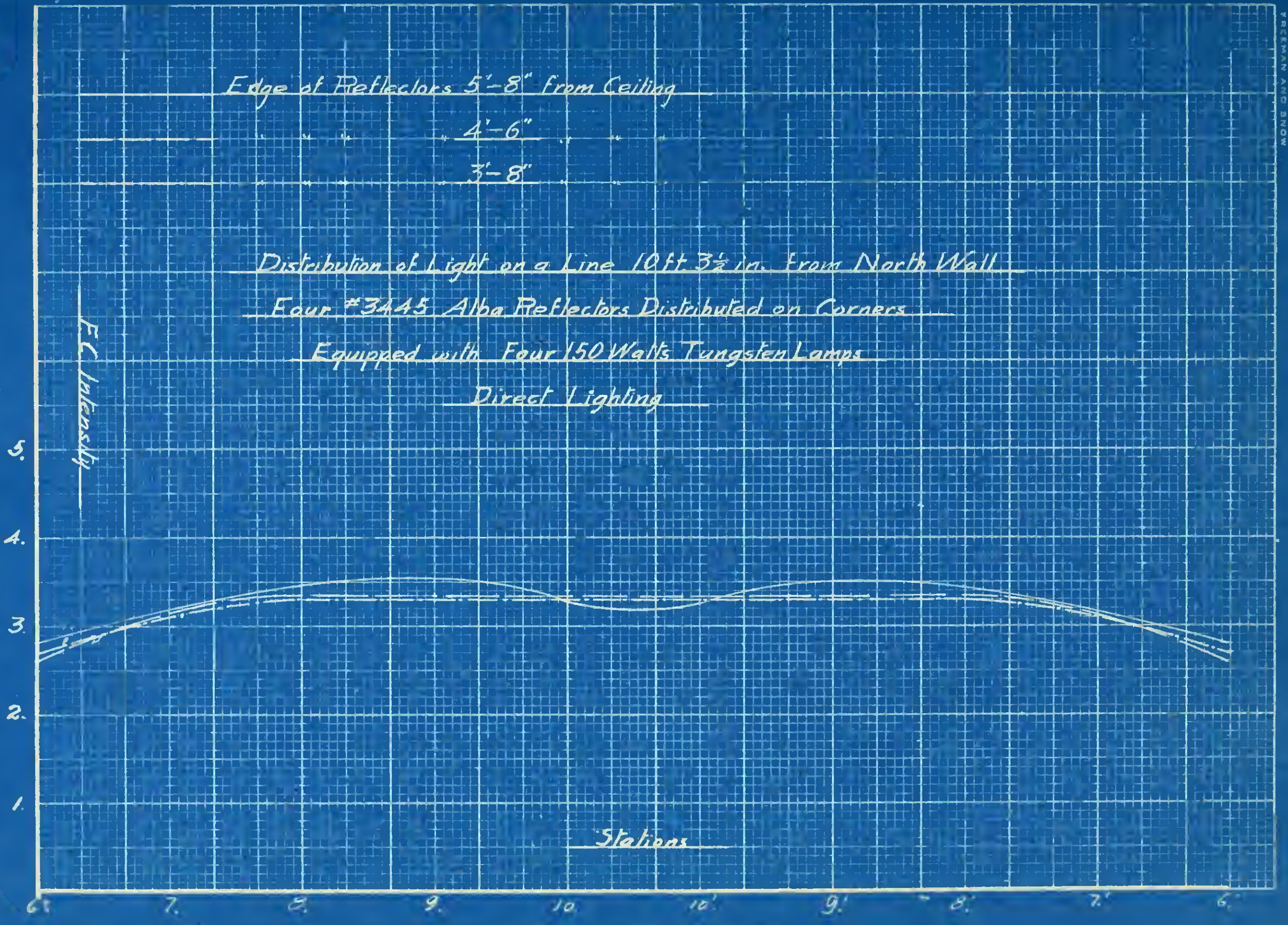
Equipped with 150 Watts Tungsten Lamps

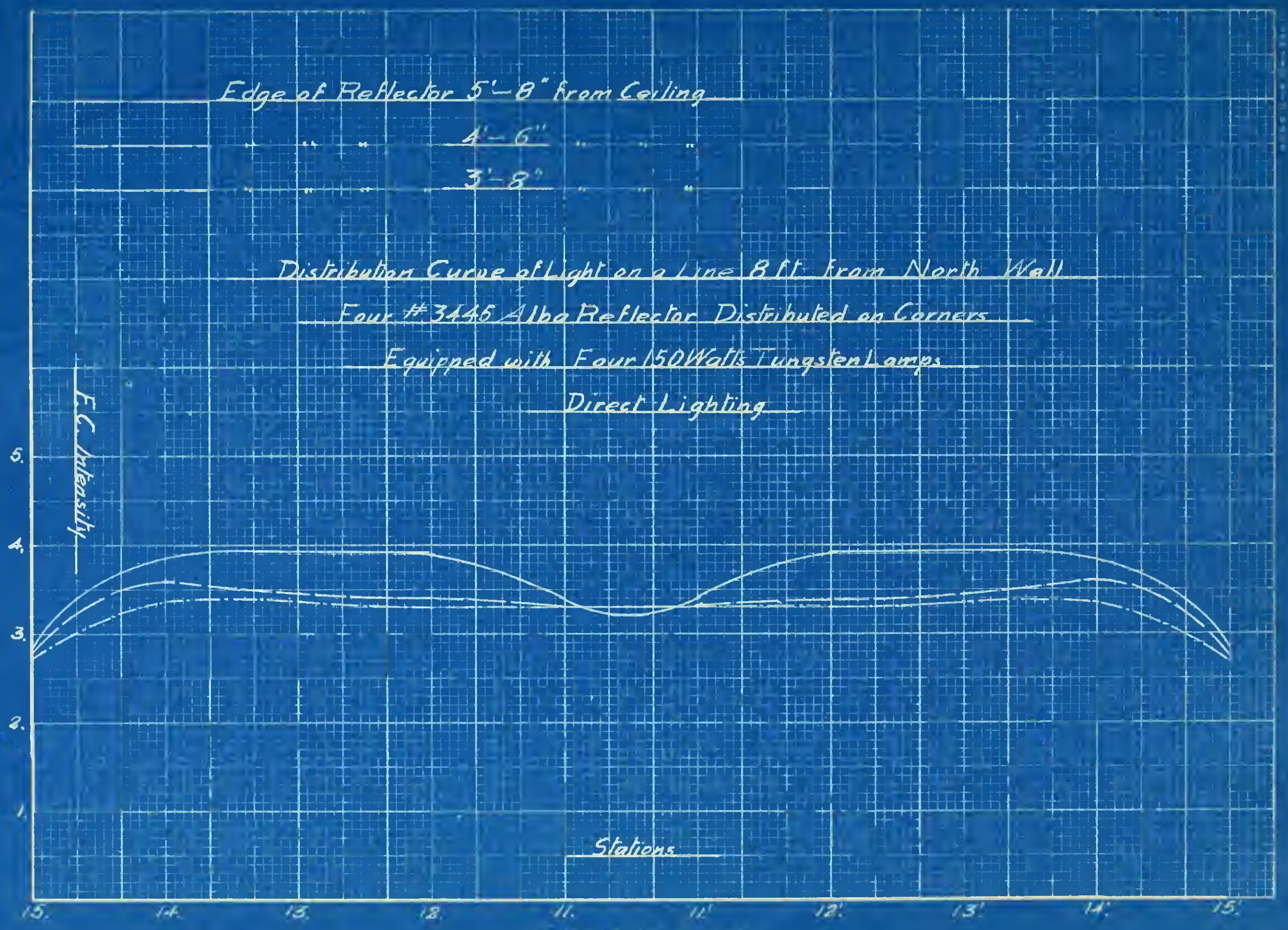
Reflectors Turned Upwards

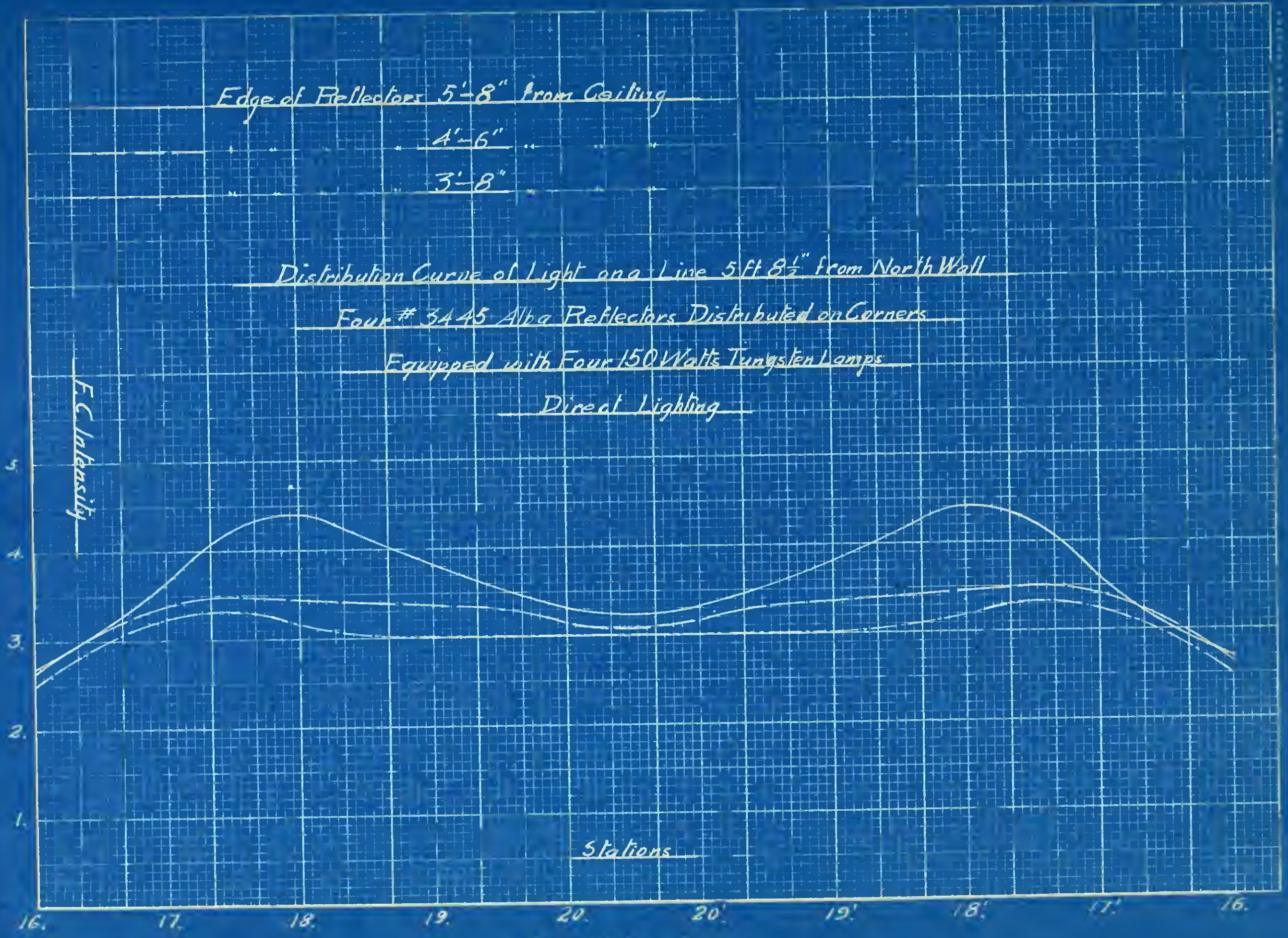
Group [illegible] Fig. [illegible]



Group III, Fig. 18


Edge of Reflectors 5'-8" from Ceiling
4'-6"
3'-8"
Distribution of Light on a Line 10 ft 3½ in. from North Wall
Four #3445 Alba Reflectors Distributed on Corners
Equipped with Four 150 Watts Tungsten Lamps
Direct Lighting
F.C. Intensity
5.
4.
3.
2.
1.
Stations
6.
7.
8.
9.
10
10'
9'
8'
7'
6'
FREEMAN AND SNOW


Edge of Reflector 5'-8" from Ceiling
" " " 4'-6" " " "
" " " 3'-8" " " "
Distribution Curve of Light on a Line 8 ft. from North Wall
Four #3446 Alba Reflector Distributed on Corners
Equipped with Four 150 Watts Tungsten Lamps
Direct Lighting
F.C. Intensity
5.
4.
3.
2.
1.
Stations
15.
14.
13.
12.
11.
11'
12'
13'
14'
15'

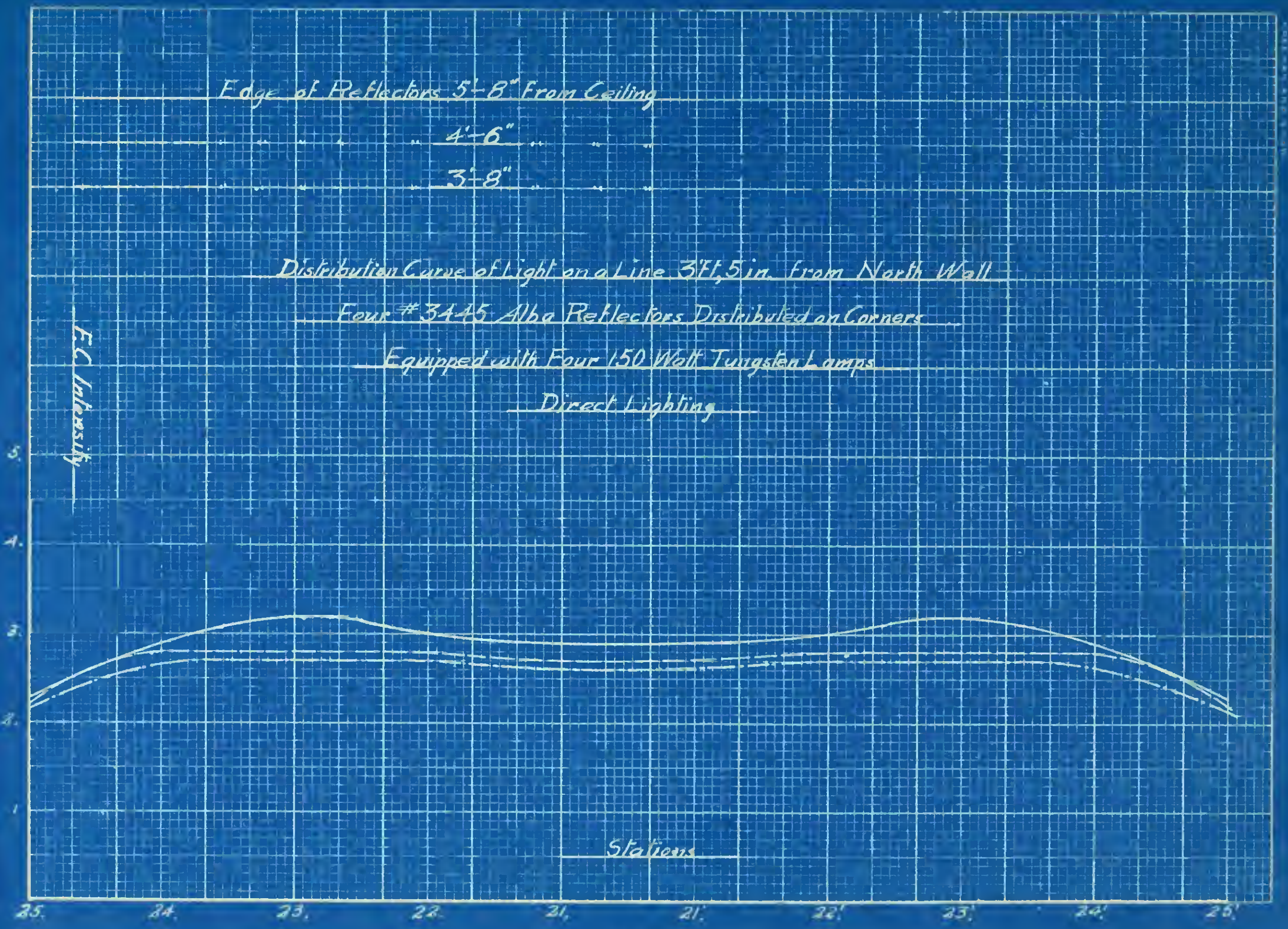


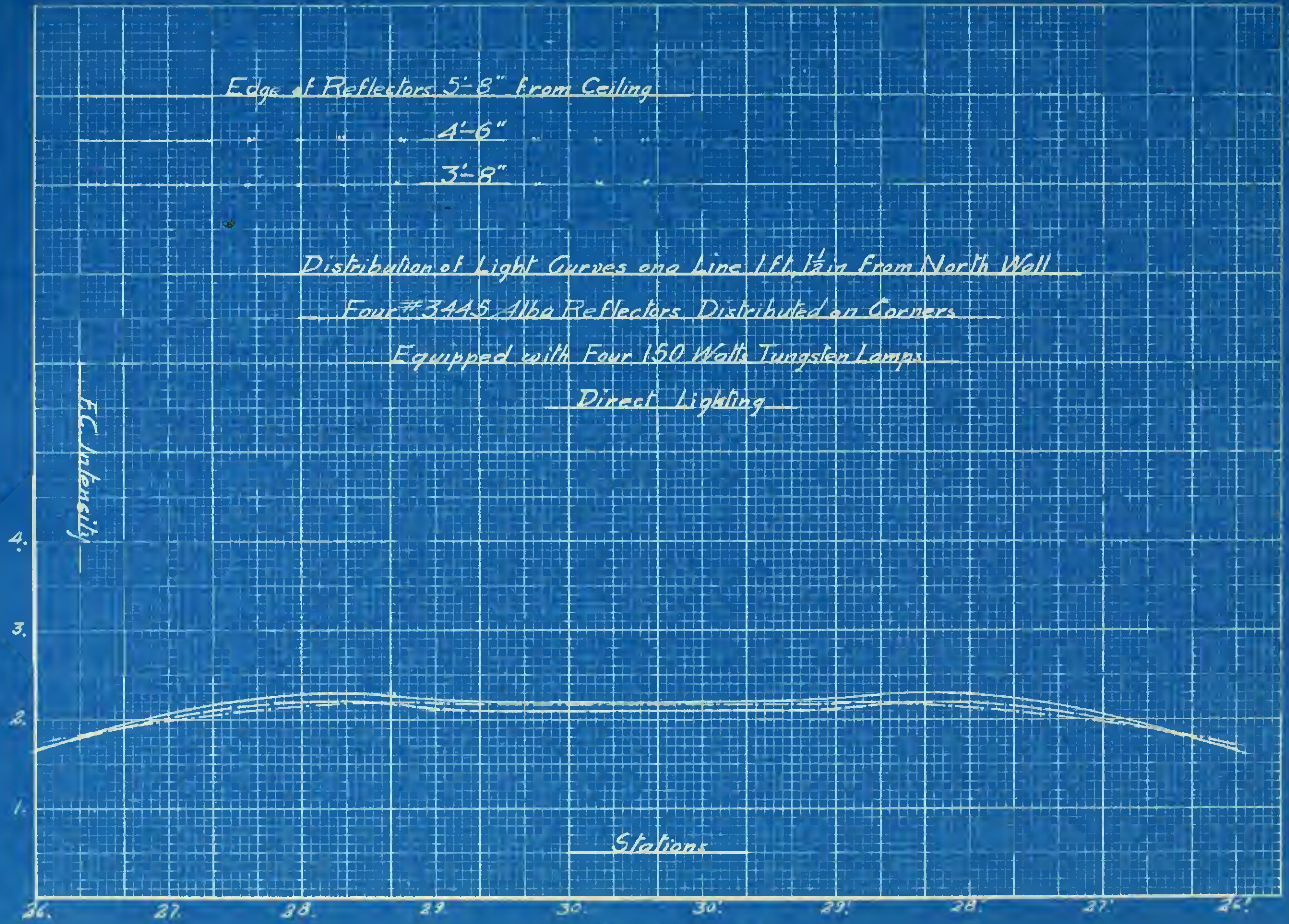
Distribution Curve of Light on a Line 5 ft 8½" from North Wall

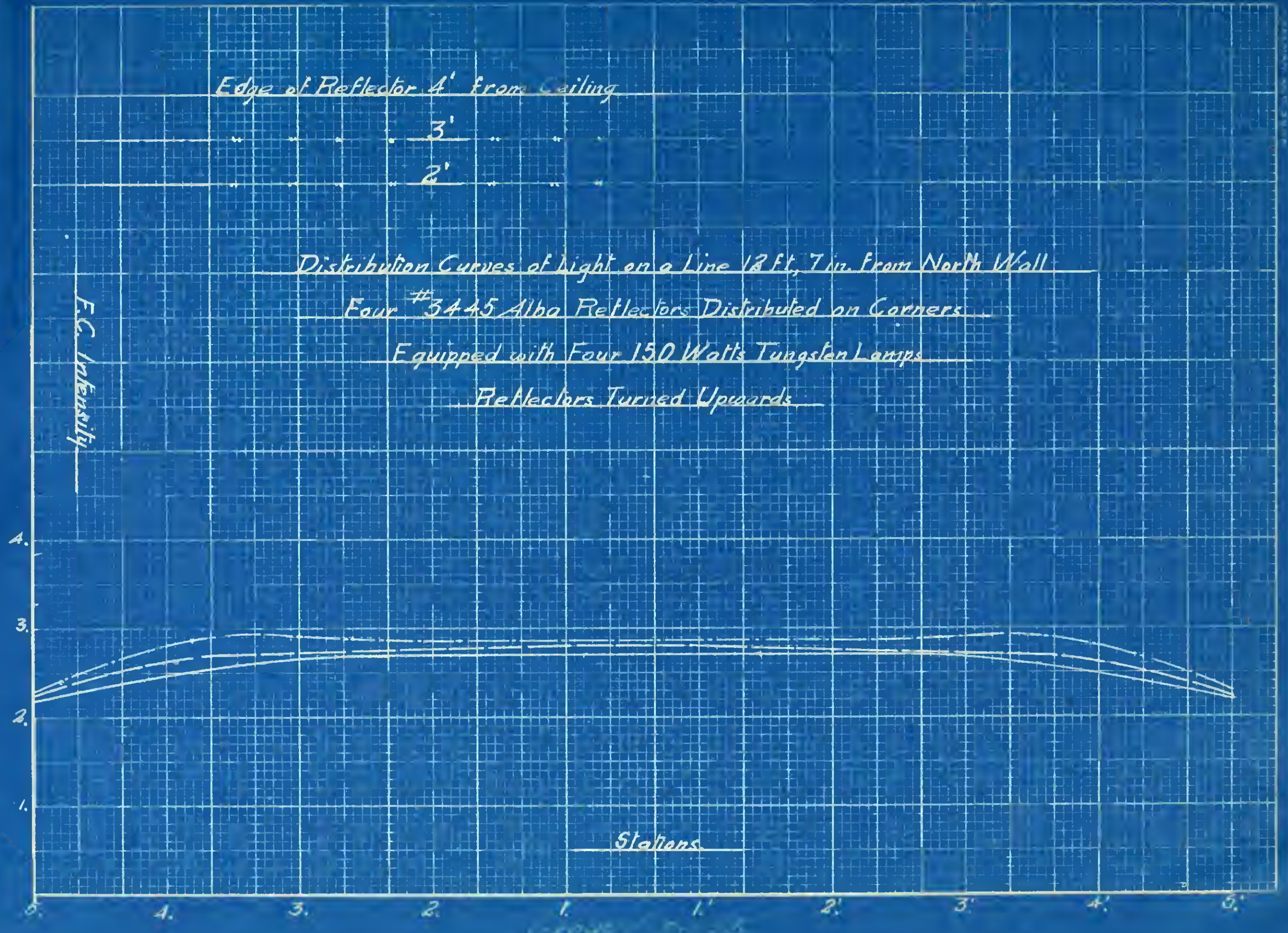
Four # 3445 Alba Reflectors Distributed on Corners

Equipped with Four 150 Watts Tungsten Lamps

Direct Lighting


Edge of Reflectors 5'-8" From Ceiling
4'-6"
3'-8"
Distribution Curve of Light on a Line 3'Ft, 5 in. from North Wall
Four #3445 Alba Reflectors Distributed on Corners
Equipped with Four 150 Watt Tungsten Lamps
Direct Lighting
F.C. Intensity
5.
4.
3.
2.
1
Stations
25.
24.
23.
22.
21.
21'.
22'.
23'.
24'.
25'.

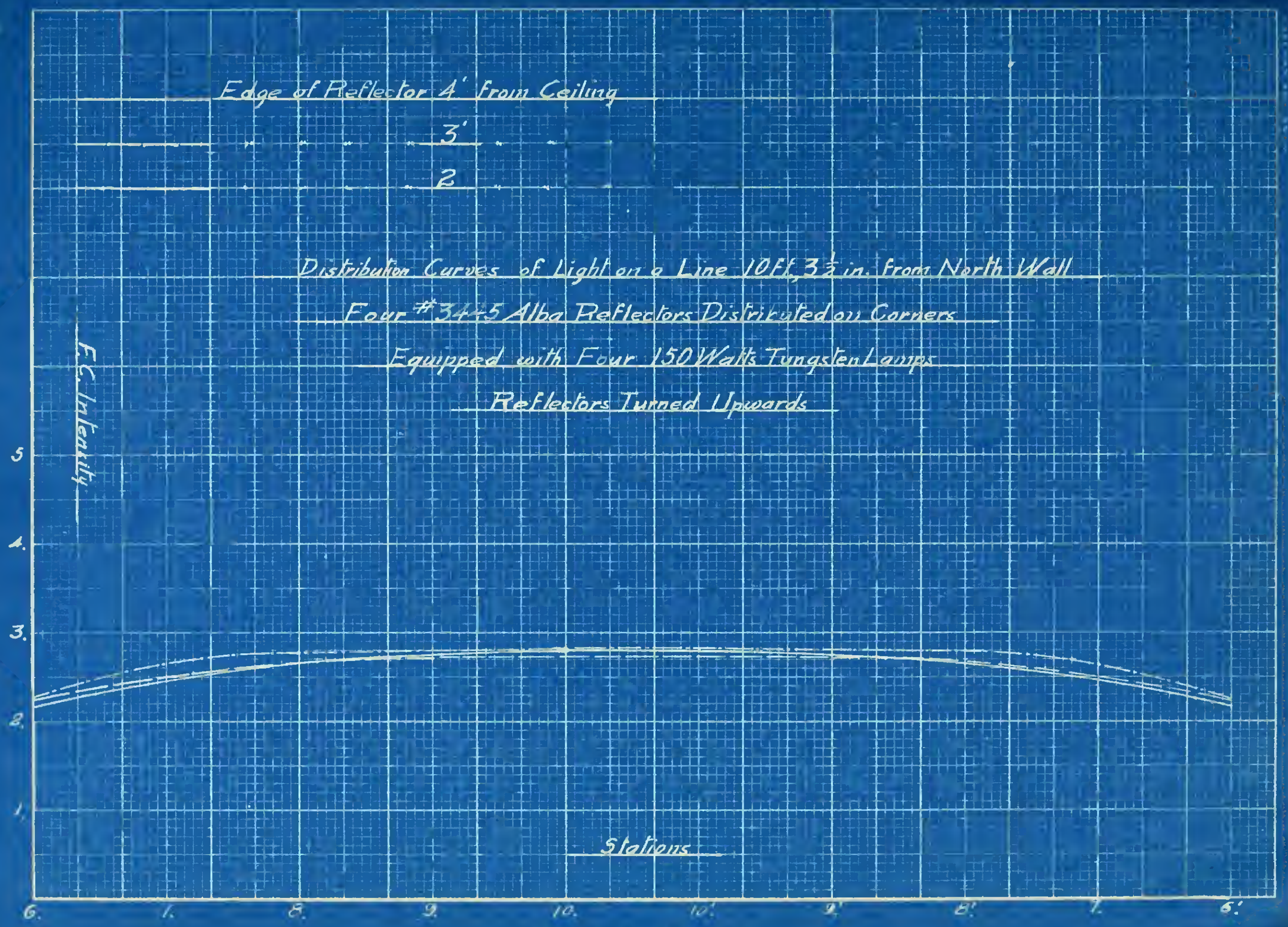

Edge of Reflectors 5'-8" from Ceiling
4'-6"
3'-8"
Distribution of Light Curves on a Line 1 ft. 1½ in. From North Wall
Four #3445 Alba Reflectors Distributed on Corners
Equipped with Four 150 Watts Tungsten Lamps
Direct Lighting
F.C. Intensity
4.
3.
2.
1.
Stations
26.
27.
28.
29.
30.
30'
29'
28'
27'
26'


Distribution Curves of Light on a Line 12 Ft, 7 in. From North Wall

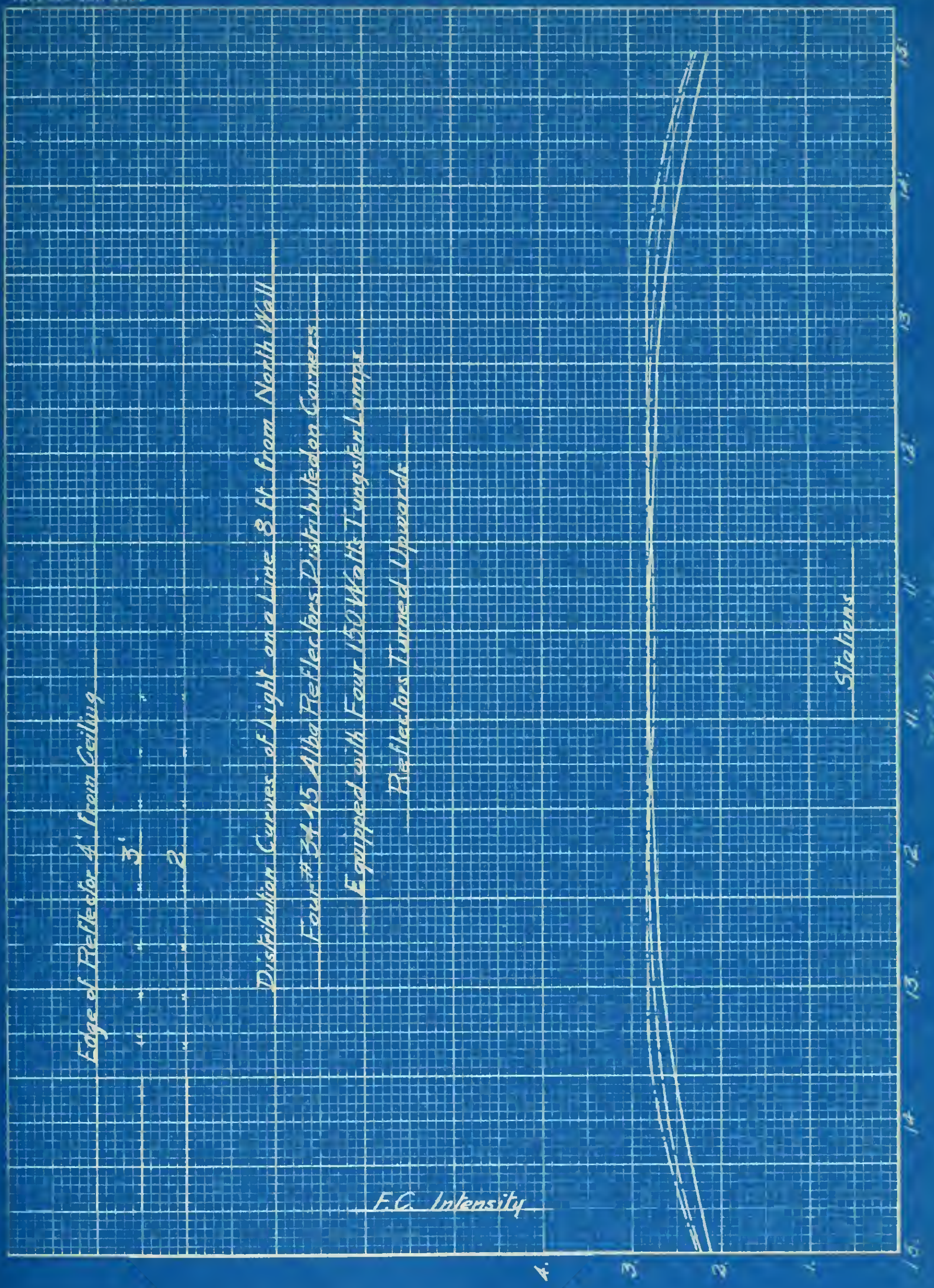
Four #3445 Alba Reflectors Distributed on Corners

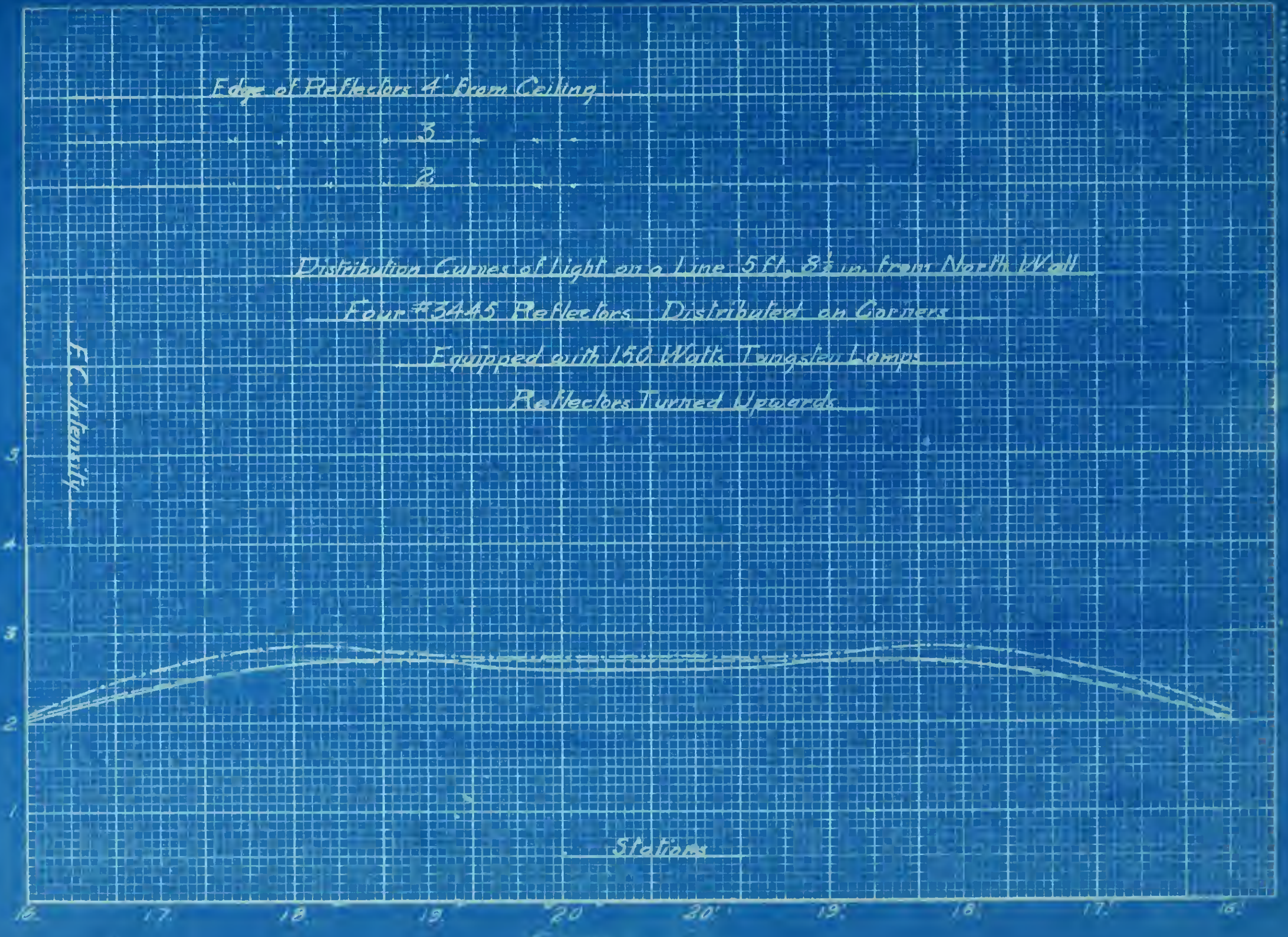
Equipped with Four 150 Watts Tungsten Lamps

Reflectors Turned Upwards


Edge of Reflector 4' From Ceiling
3'
2
Distribution Curves of Light on a Line 10 Ft, 3½ in. From North Wall
Four #3445 Alba Reflectors Distributed on Corners
Equipped with Four 150 Watts Tungsten Lamps
Reflectors Turned Upwards
F.C. Intensity
5
4.
3.
2.
1.
Stations
6.
7.
8.
9.
10.
10'
9'
8'
7.
6'

[illegible]


Edge of Reflector 4' from Ceiling
3'
2'
Distribution Curves of Light on a Line 8 Ft. from North Wall
Four #3445 Alba Reflectors Distributed on Corners
Equipped with Four 150 Watts Tungsten Lamps
Reflectors Turned Upwards
Stations
F.C. Intensity
4.
3
2
1
10
14
13
12
11
11
12
13
14
15

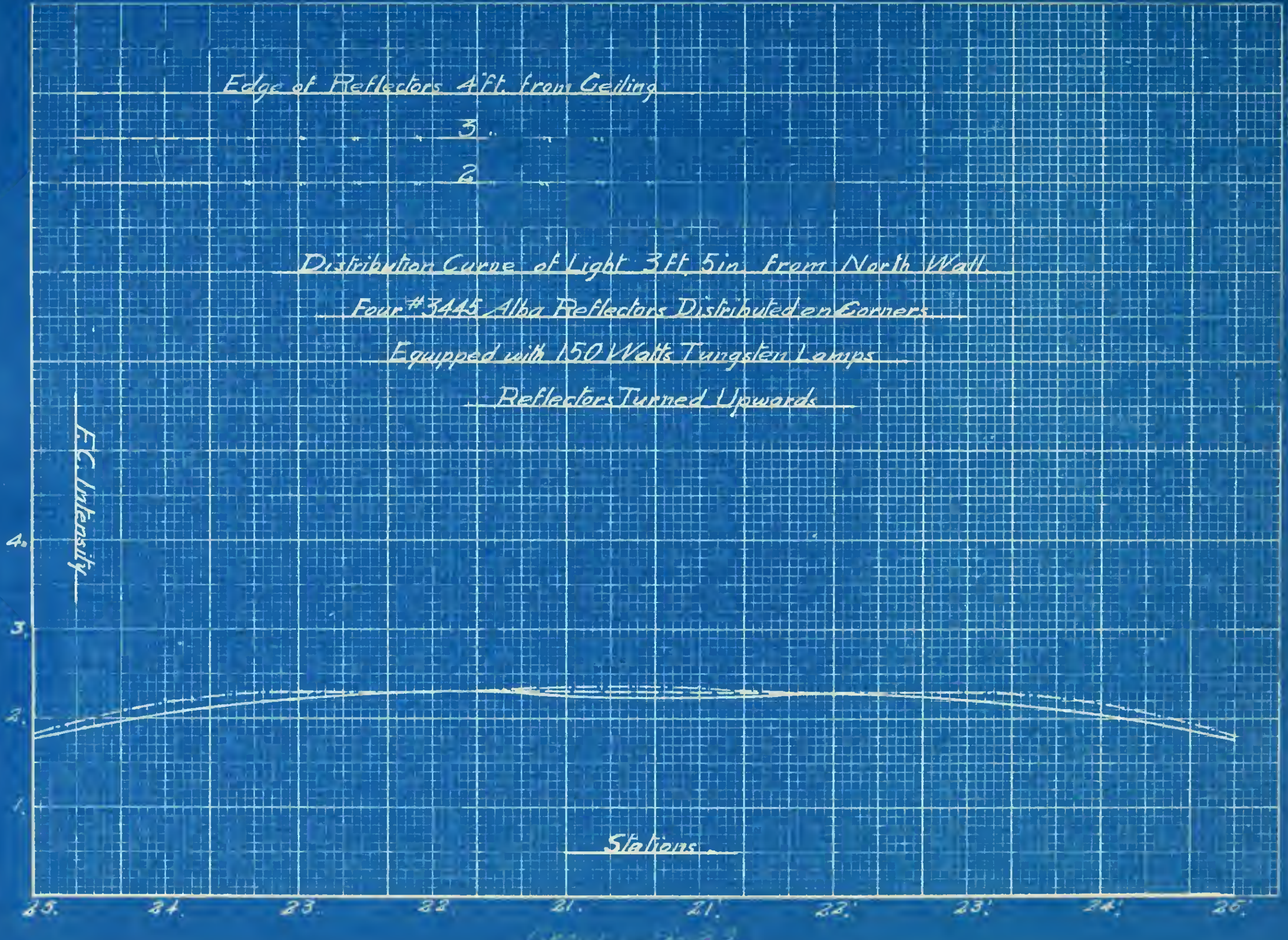


Distribution Curves of Light on a Line 5 ft. 8½ in. from North Wall

Four #3445 Reflectors Distributed on Corners

Equipped with 150 Watts Tungsten Lamps

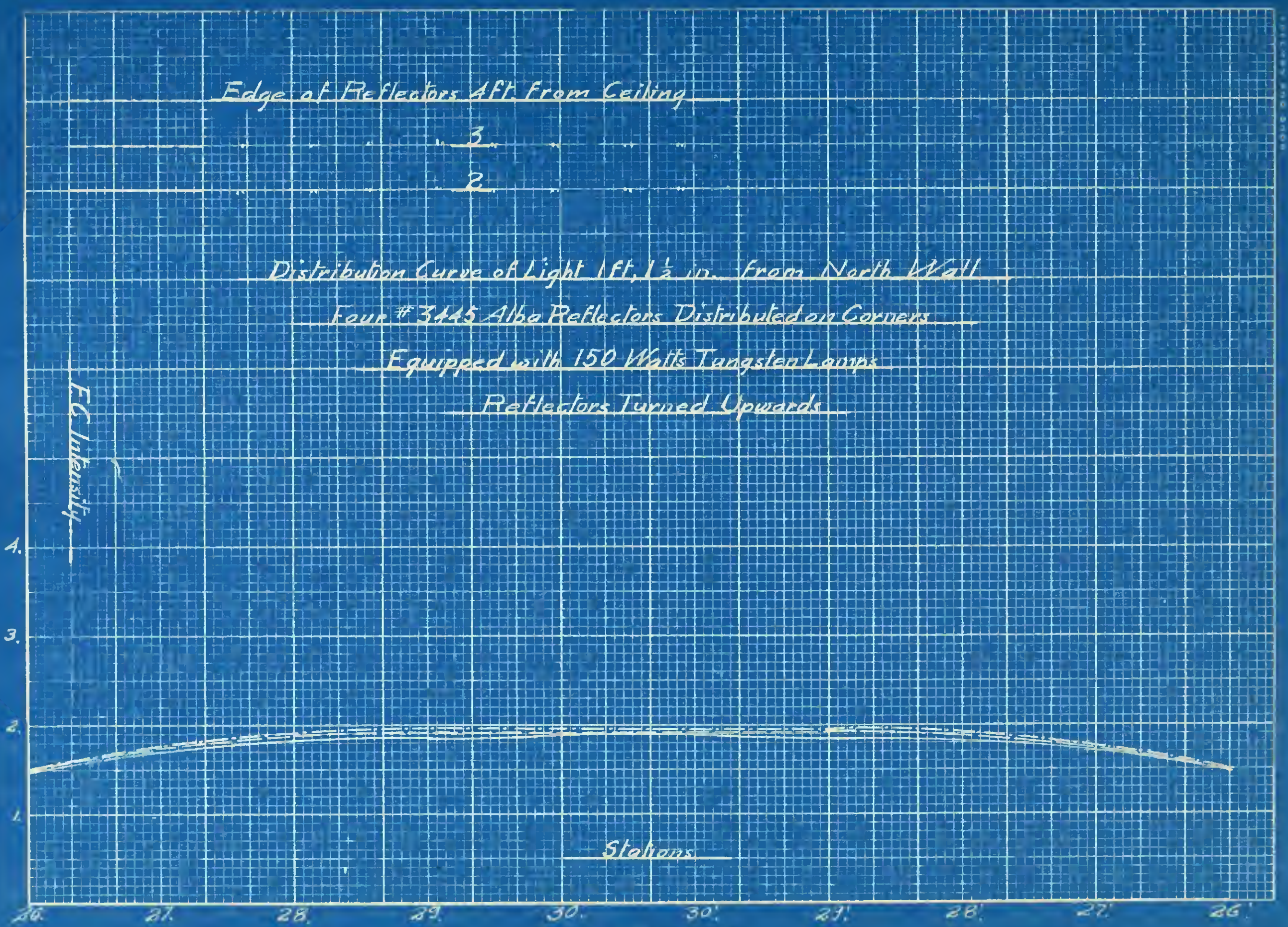
Reflectors Turned Upwards


Distribution Curve of Light 3 Ft. 5 in. from North Wall

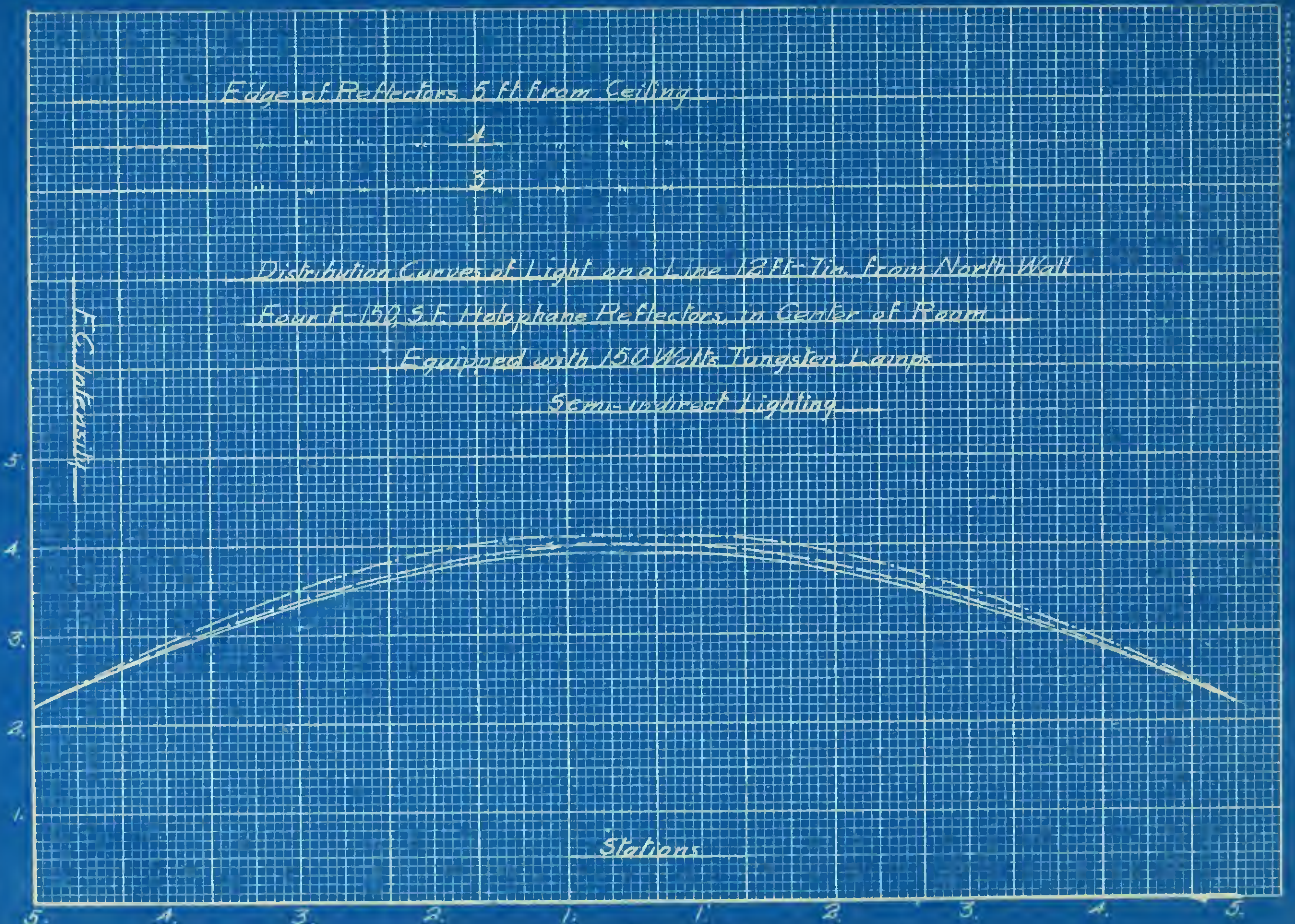
Four #3445 Alba Reflectors Distributed on Corners

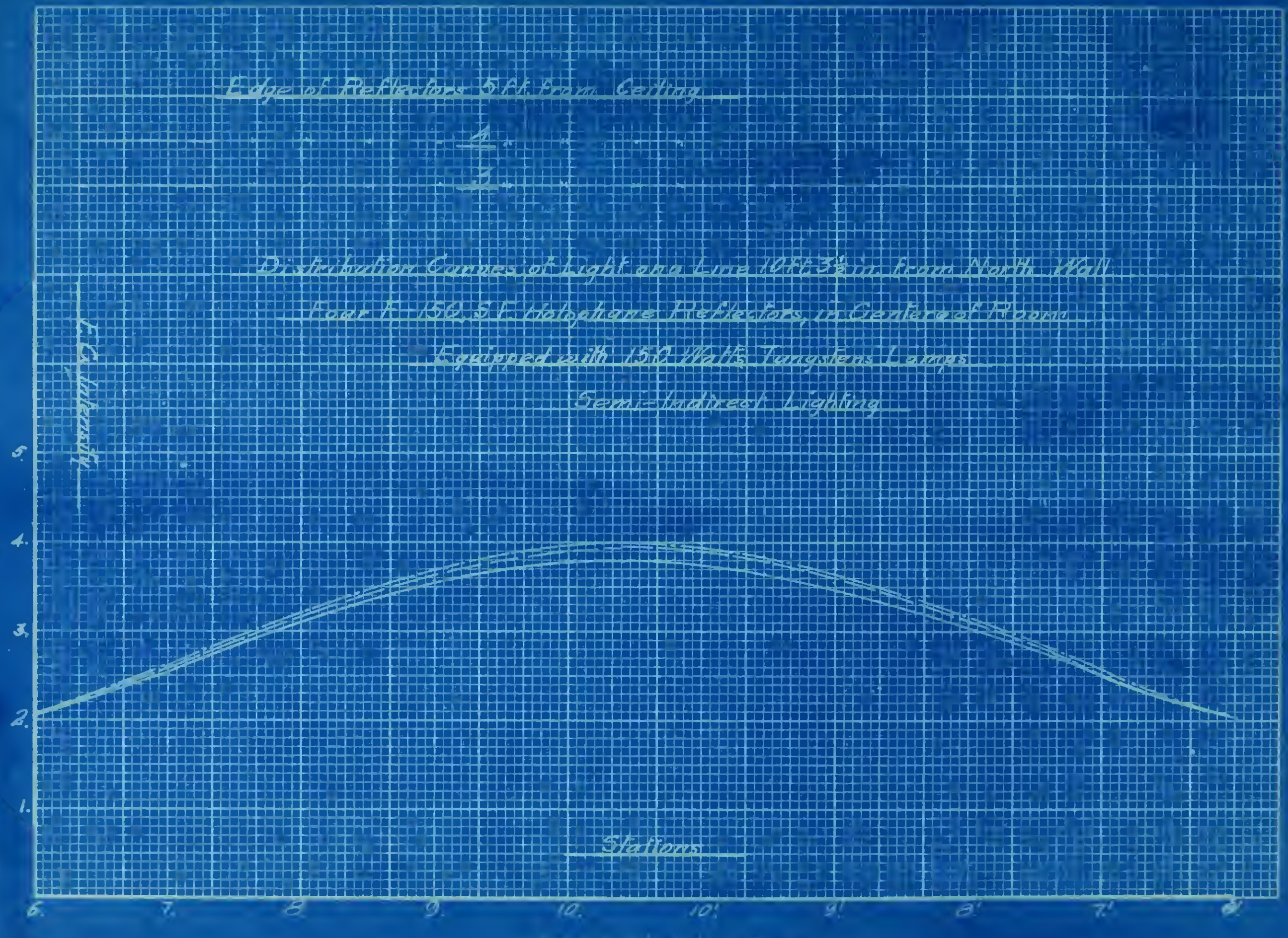
Equipped with 150 Watts Tungsten Lamps

Reflectors Turned Upwards


Edge of Reflectors 4Ft. From Ceiling
3
2
Distribution Curve of Light 1 Ft. 1½ in. From North Wall
Four #3445 Alba Reflectors Distributed on Corners
Equipped with 150 Watts Tungsten Lamps
Reflectors Turned Upwards
F.C. Intensity
4.
3.
2.
1.
Stations
26.
27.
28.
29.
30.
30.'
29.'
28.'
27.'
26.'

Group I, Fig. 2


Edge of Reflectors 5 Ft From Ceiling
4
3
Distribution Curves of Light on a Line 12 Ft-7in. from North Wall
Four F-150 S.F. Holophane Reflectors in Center of Room
Equipped with 150 Watts Tungsten Lamps
Semi-indirect Lighting
F.C. Intensity
5.
4.
3.
2.
1.
Stations
5.
4.
3.
2.
1.
1.
2.
3.
4.
5.



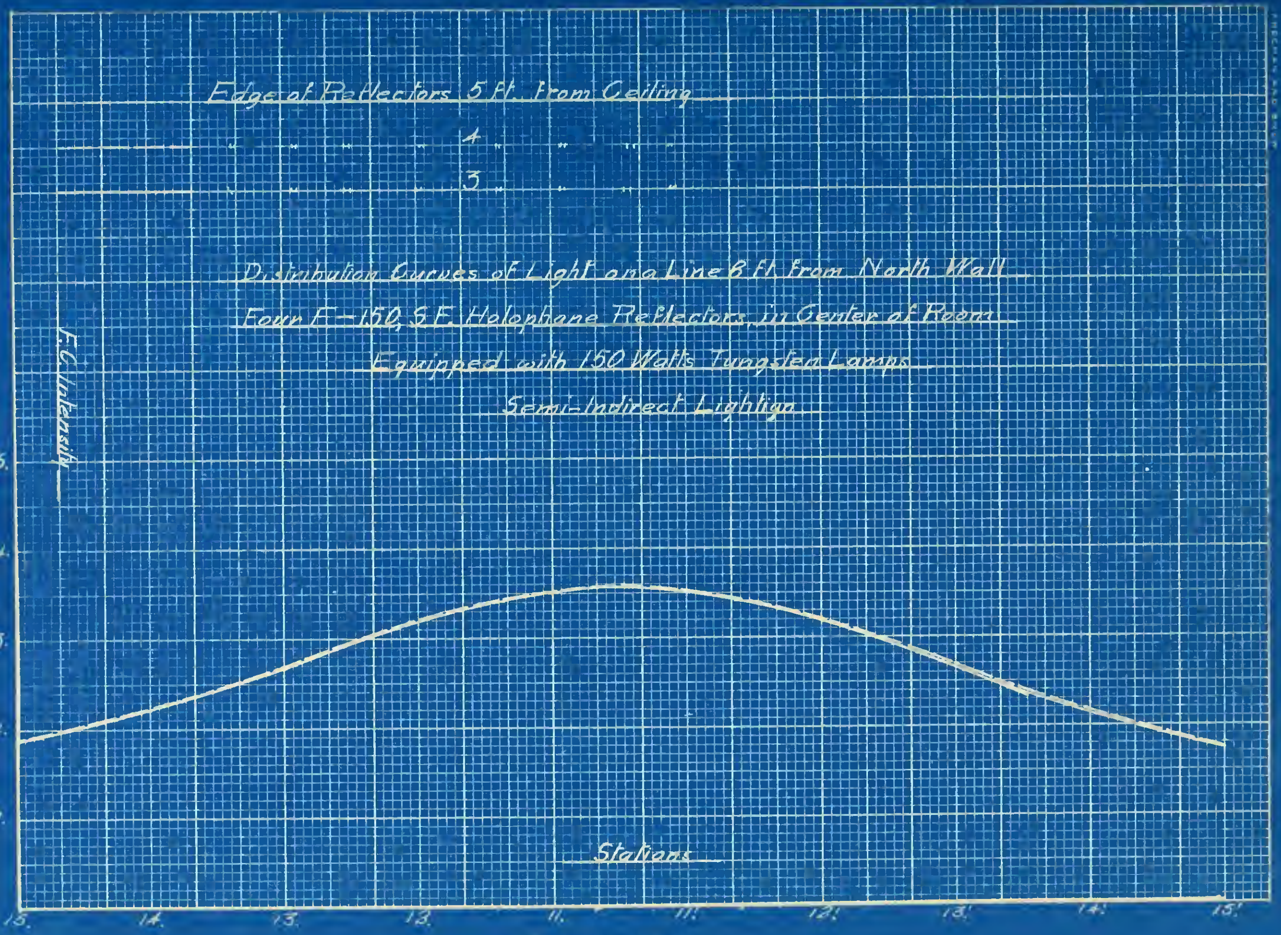
Edge of Reflectors 5 ft. from Ceiling

Distribution Curves of Light on Line 10 ft 3½ in. from North Wall

Four F. 150 S.E. Holophane Reflectors, in Center of Room

Equipped with 150 Watts Tungstens Lamps

Semi-Indirect Lighting



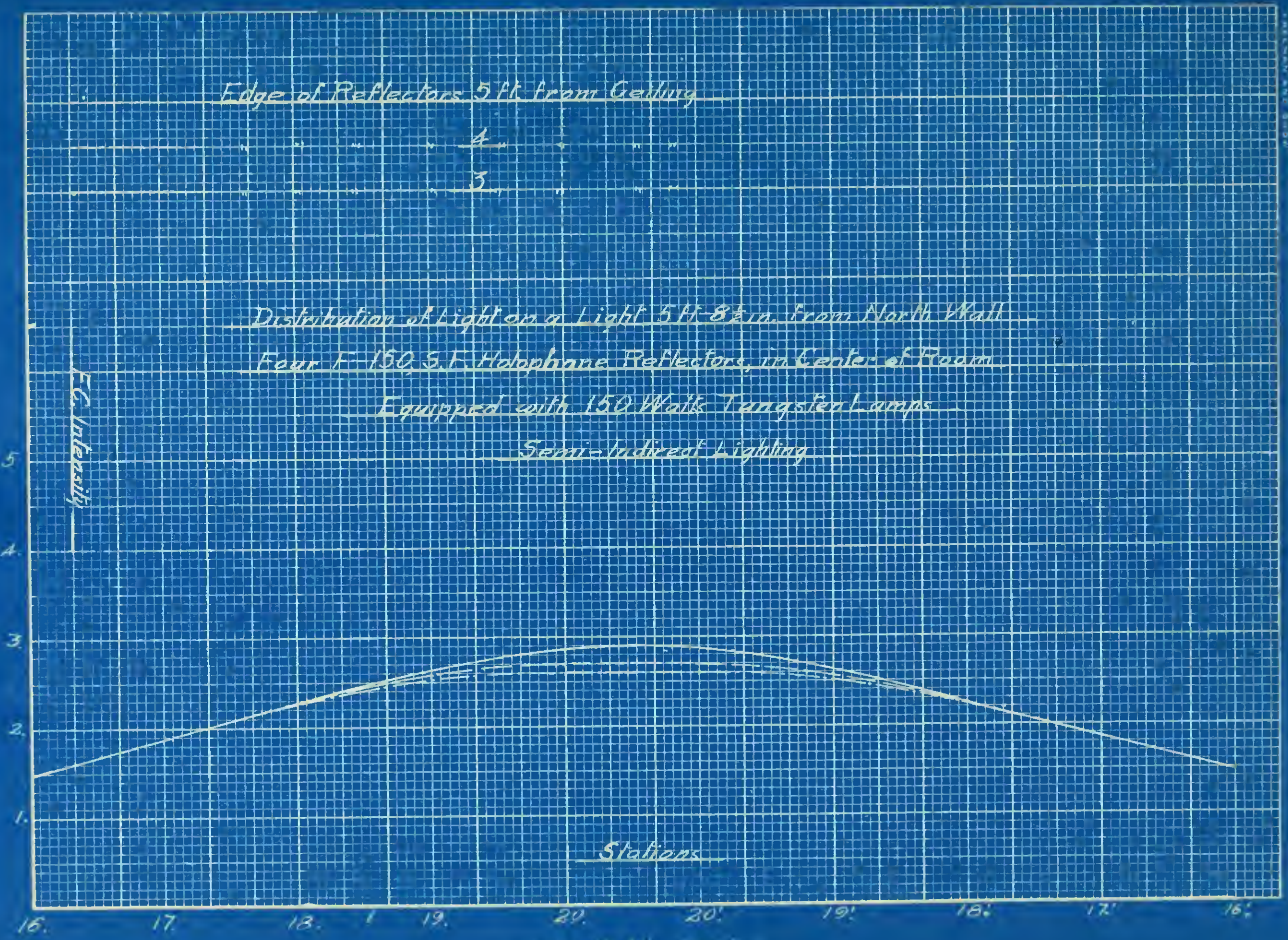
Distribution Curves of Light on a Line 8 Ft. from North Wall

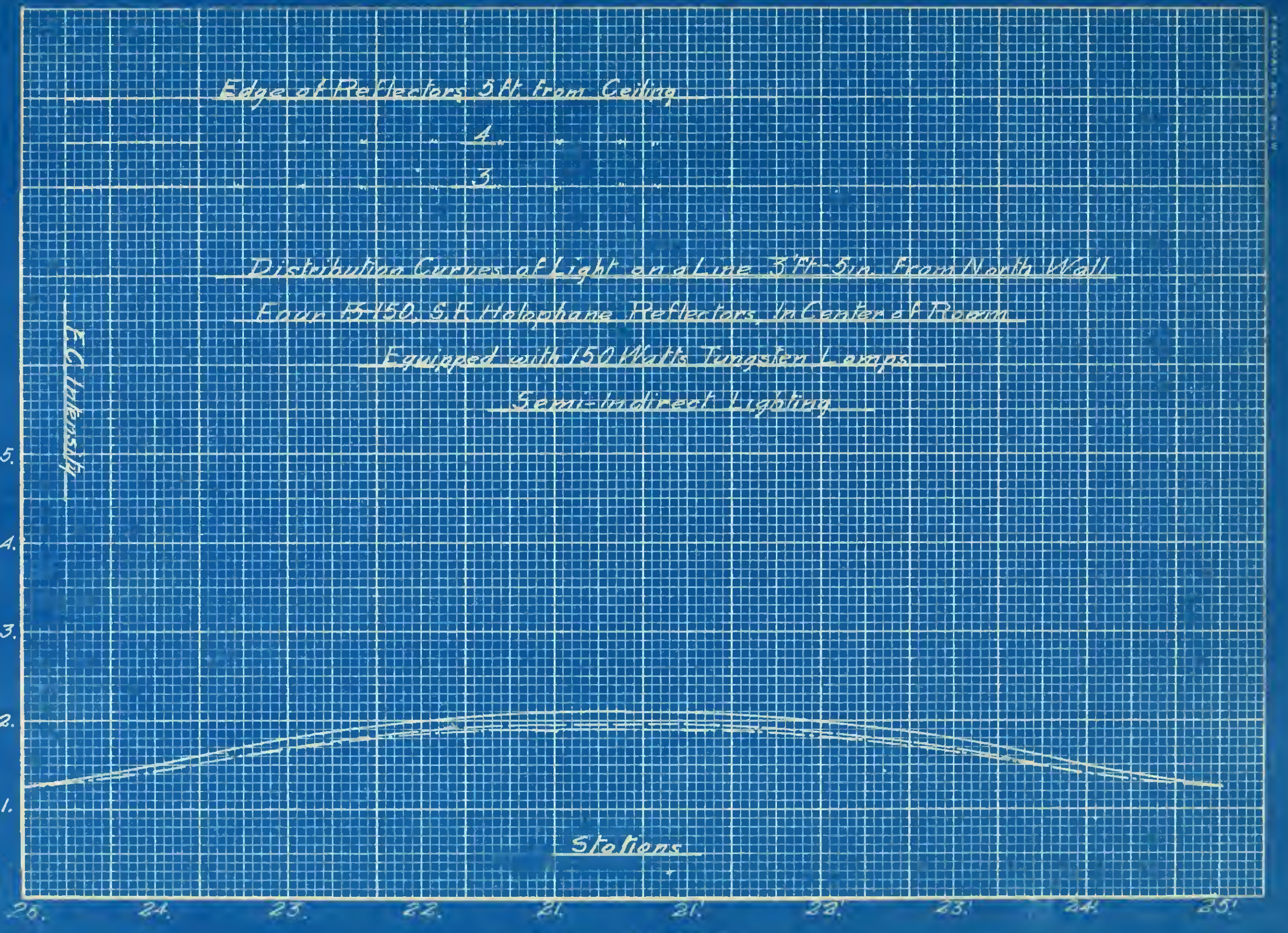
Four F-150, S.E. Holophane Reflectors in Center of Room

Equipped with 150 Watts Tungsten Lamps

Semi-Indirect Lighting

Group II. Fig. 55


Edge of Reflectors 5 ft from Ceiling
4
3
Distribution of Light on a Light 5 ft 8½ in. from North Wall
Four F-150 S.F. Holophane Reflectors, in Center of Room
Equipped with 150 Watt Tungsten Lamps
Semi-Indirect Lighting
F.C. Intensity
5
4
3
2.
1.
Stations
16.
17.
18.
1
19.
20.
20'
19'
18'
17'
16'



Distribution Curves of Light on a Line 3 Ft. 5 in. From North Wall

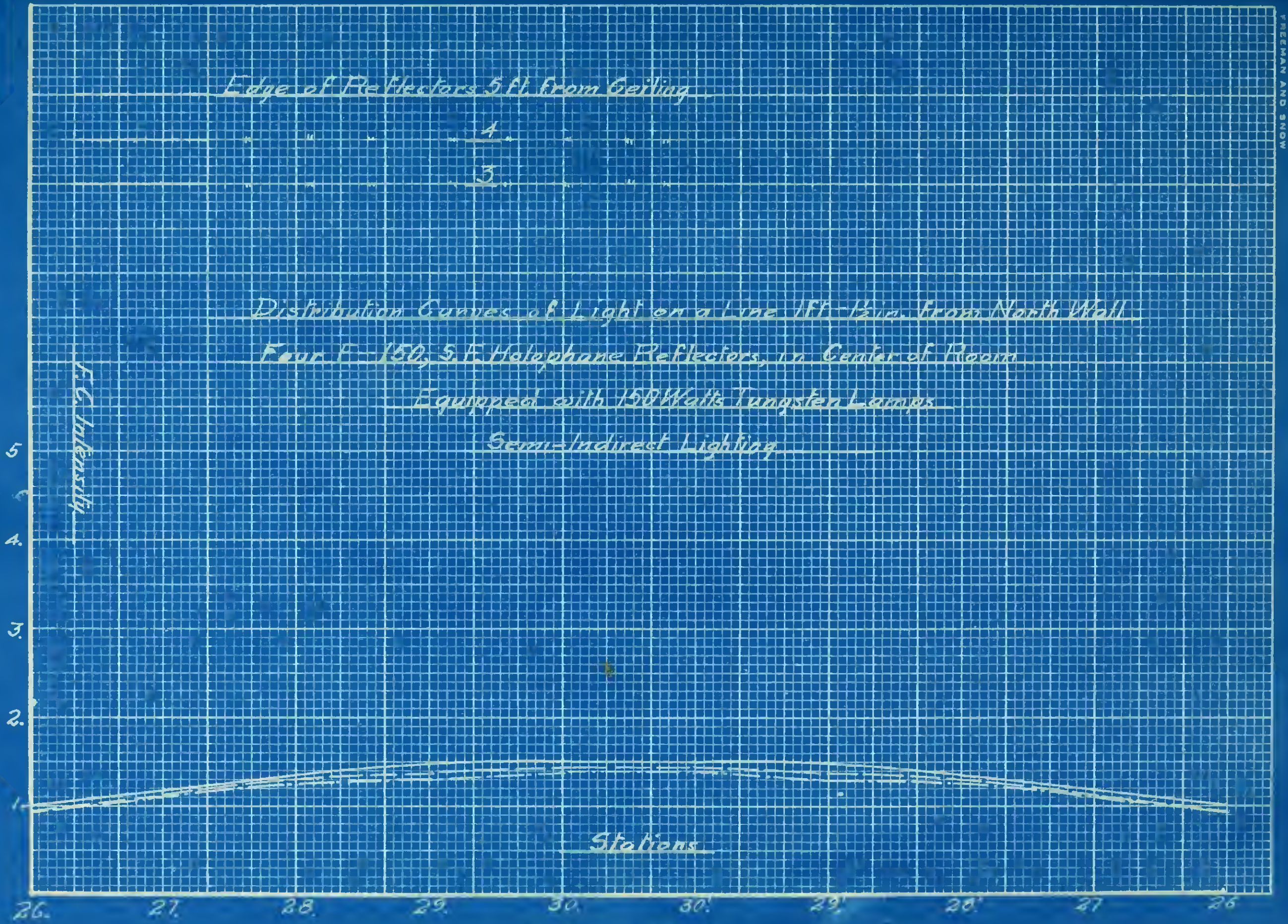
Four B-150 S.E. Holophane Reflectors In Center of Room

Equipped with 150 Watts Tungsten Lamps

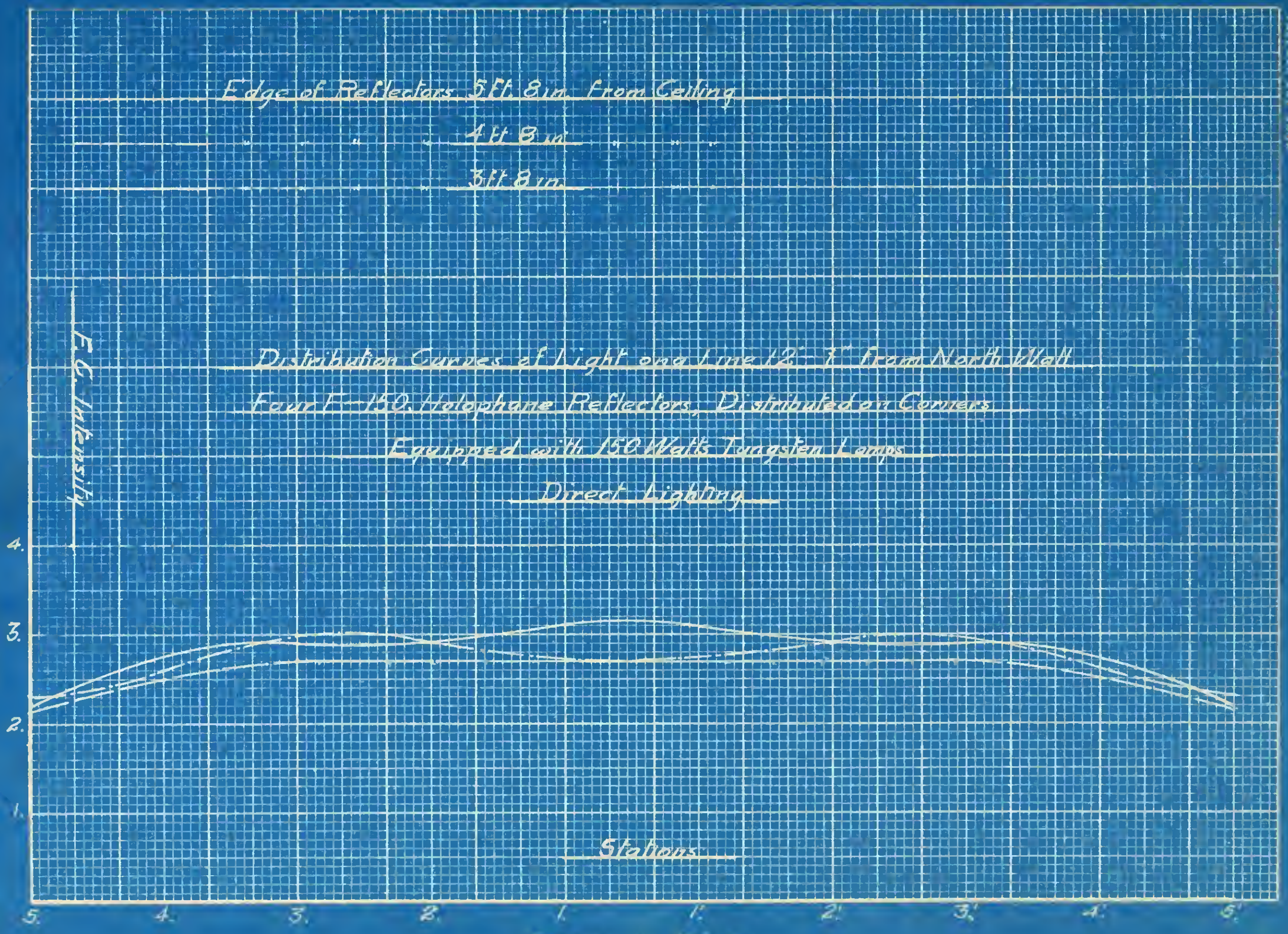
Semi-Indirect Lighting

FREEMAN AND SHAW

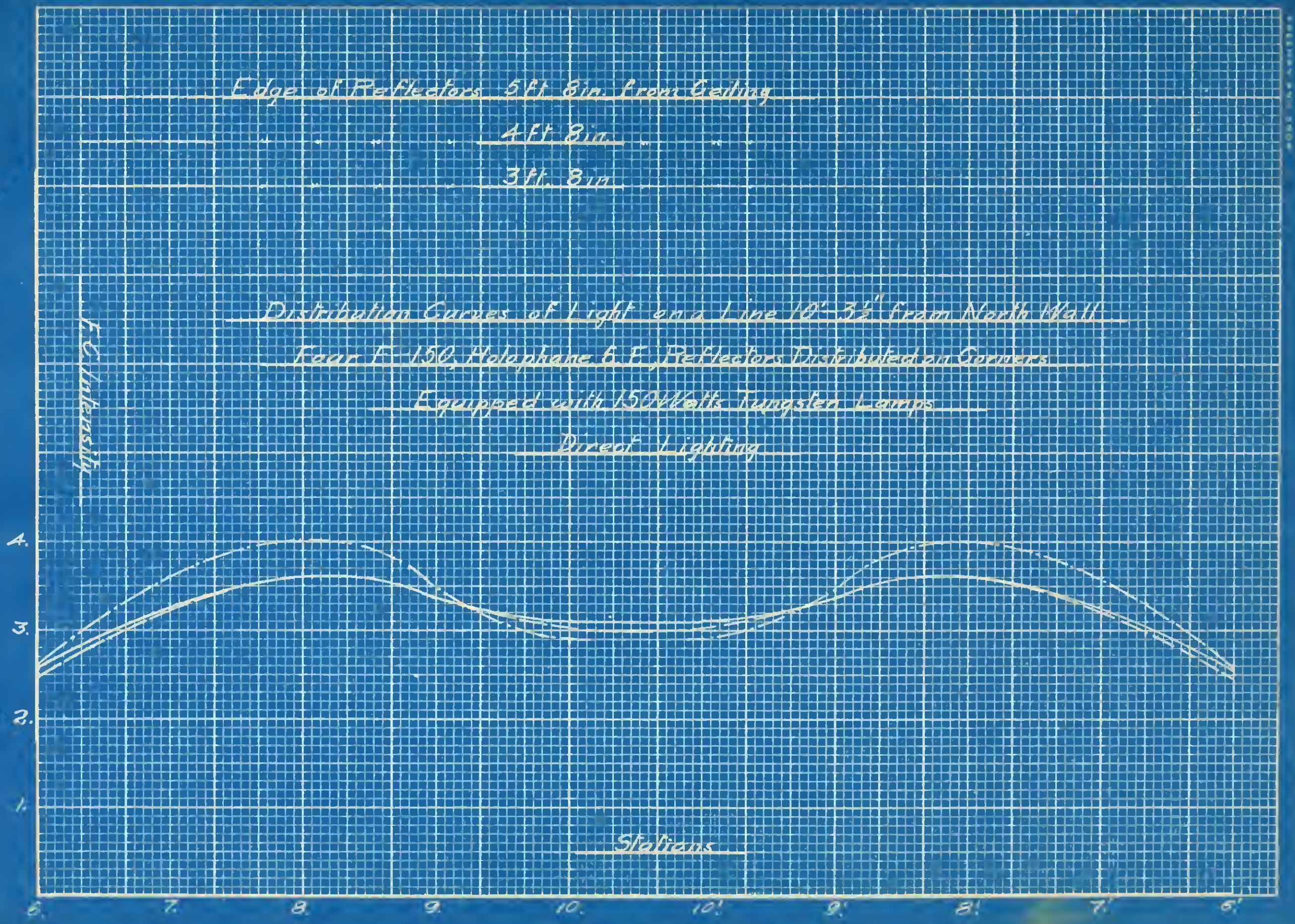
Group III. Fig. 35



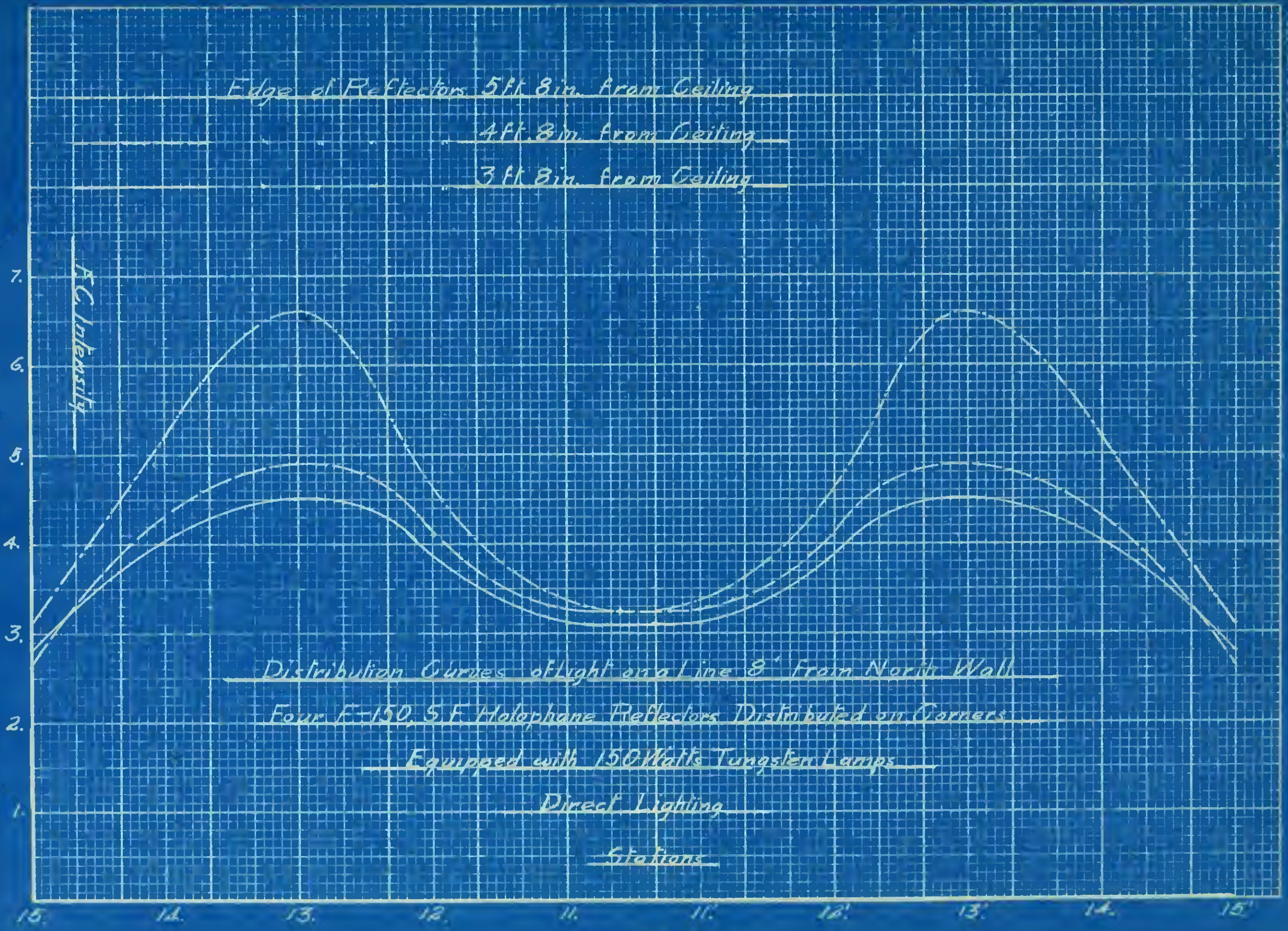
Group IV Fig. 3



(Group II. Fig. 32)



Chap VIII. Fig. 38

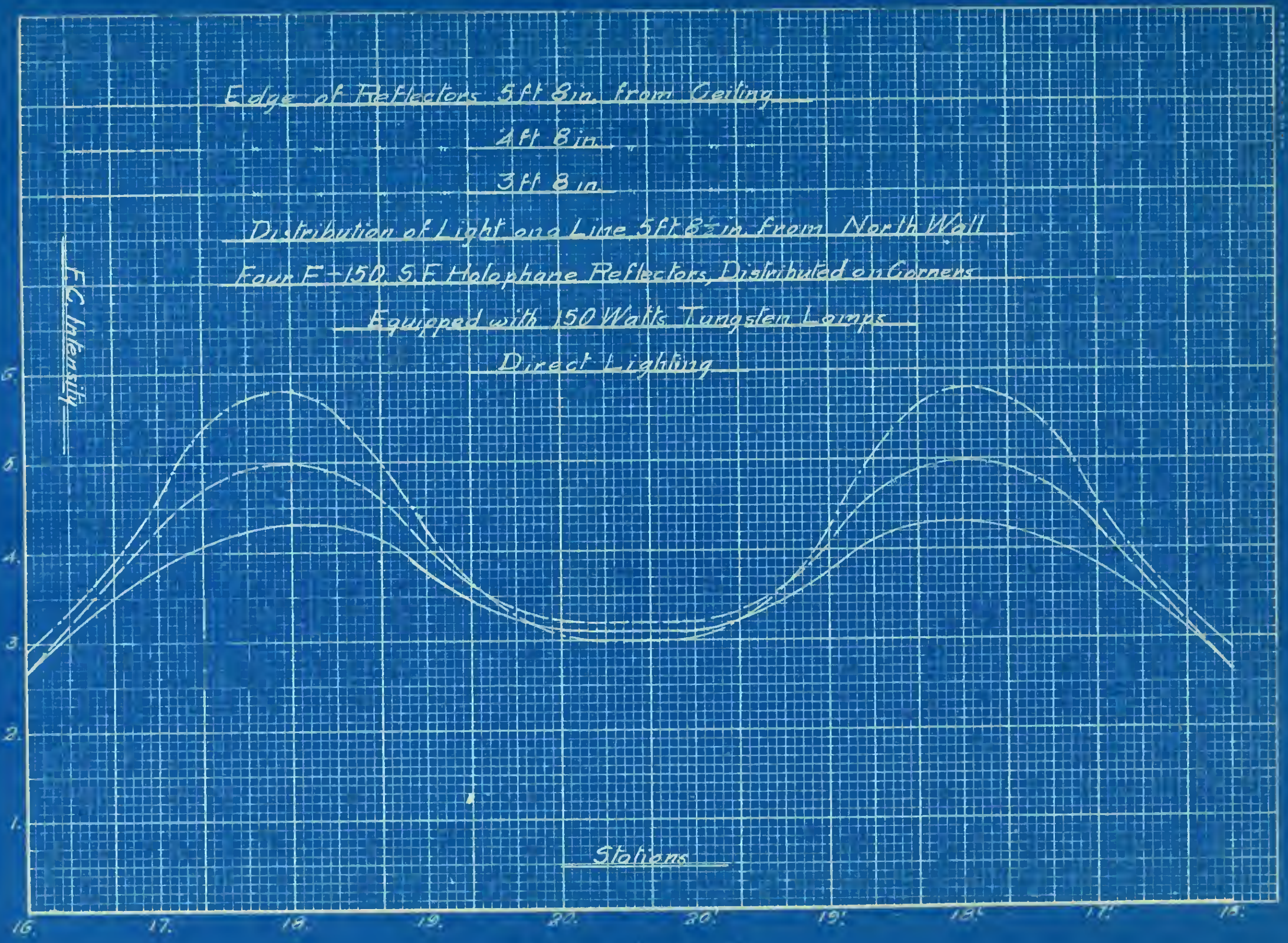


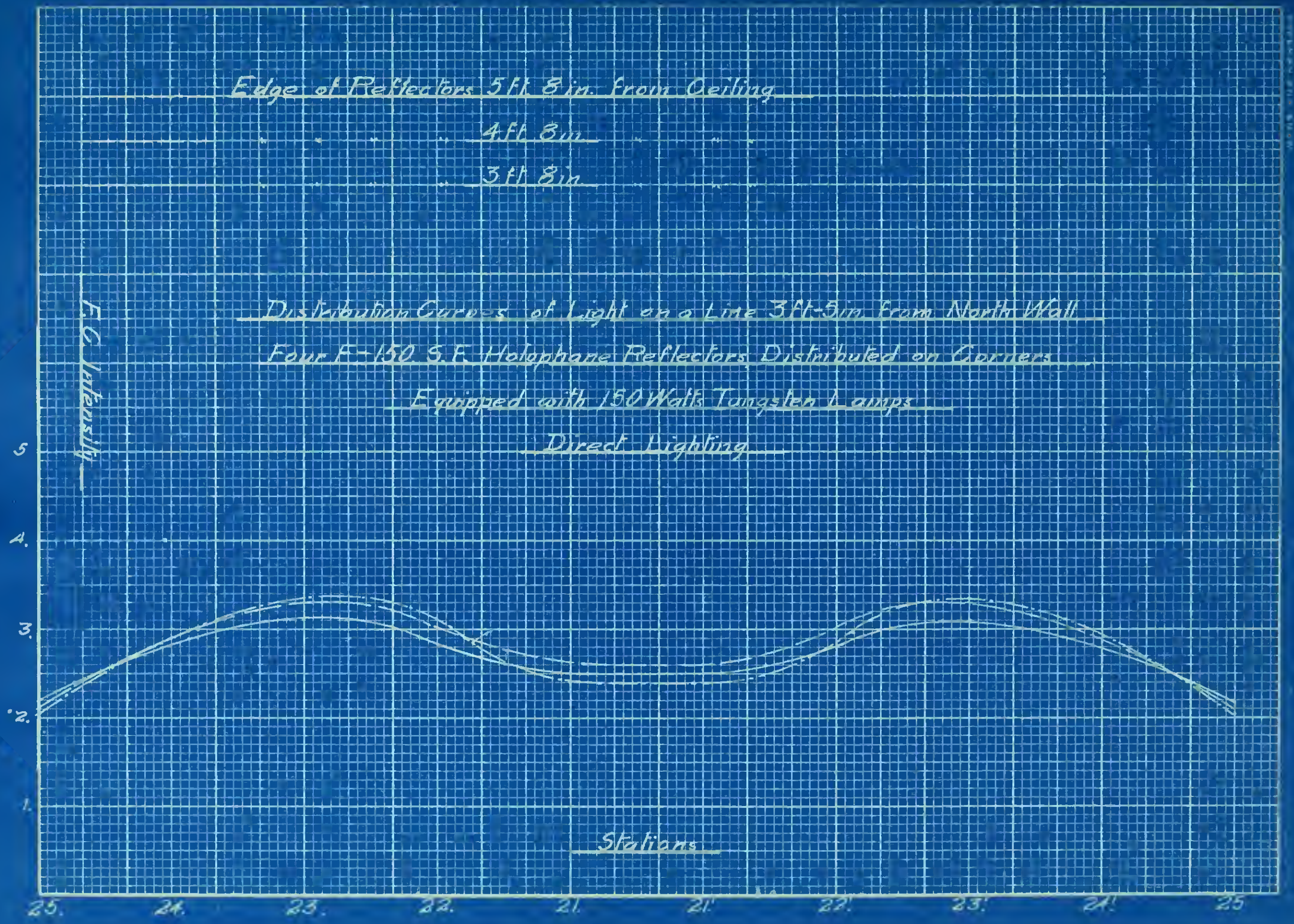
Distribution Curves of Light on a Line 8' from North Wall

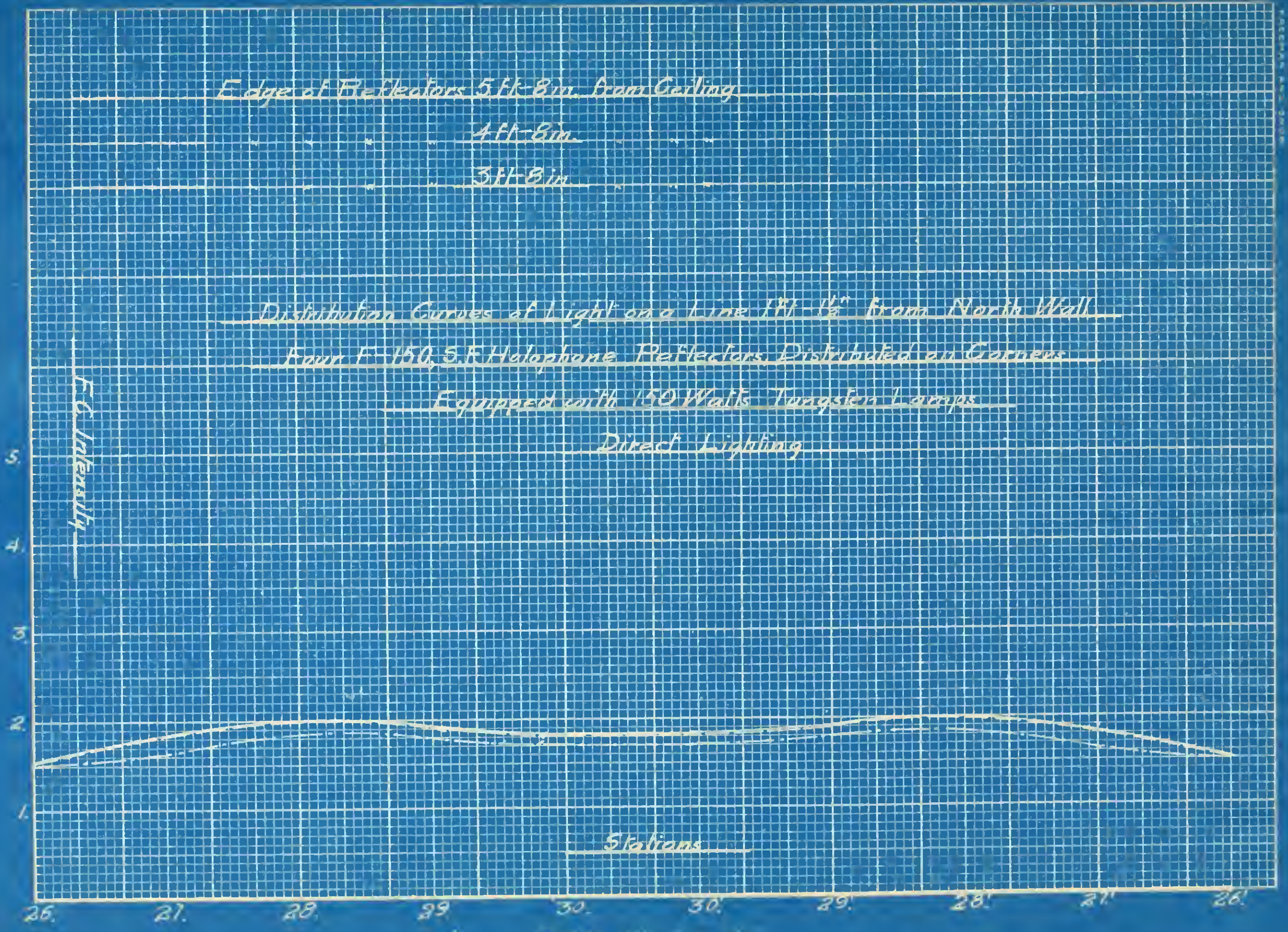
Four F-150, S.F. Holophane Reflectors Distributed on Corners

Equipped with 150 Watts Tungsten Lamps

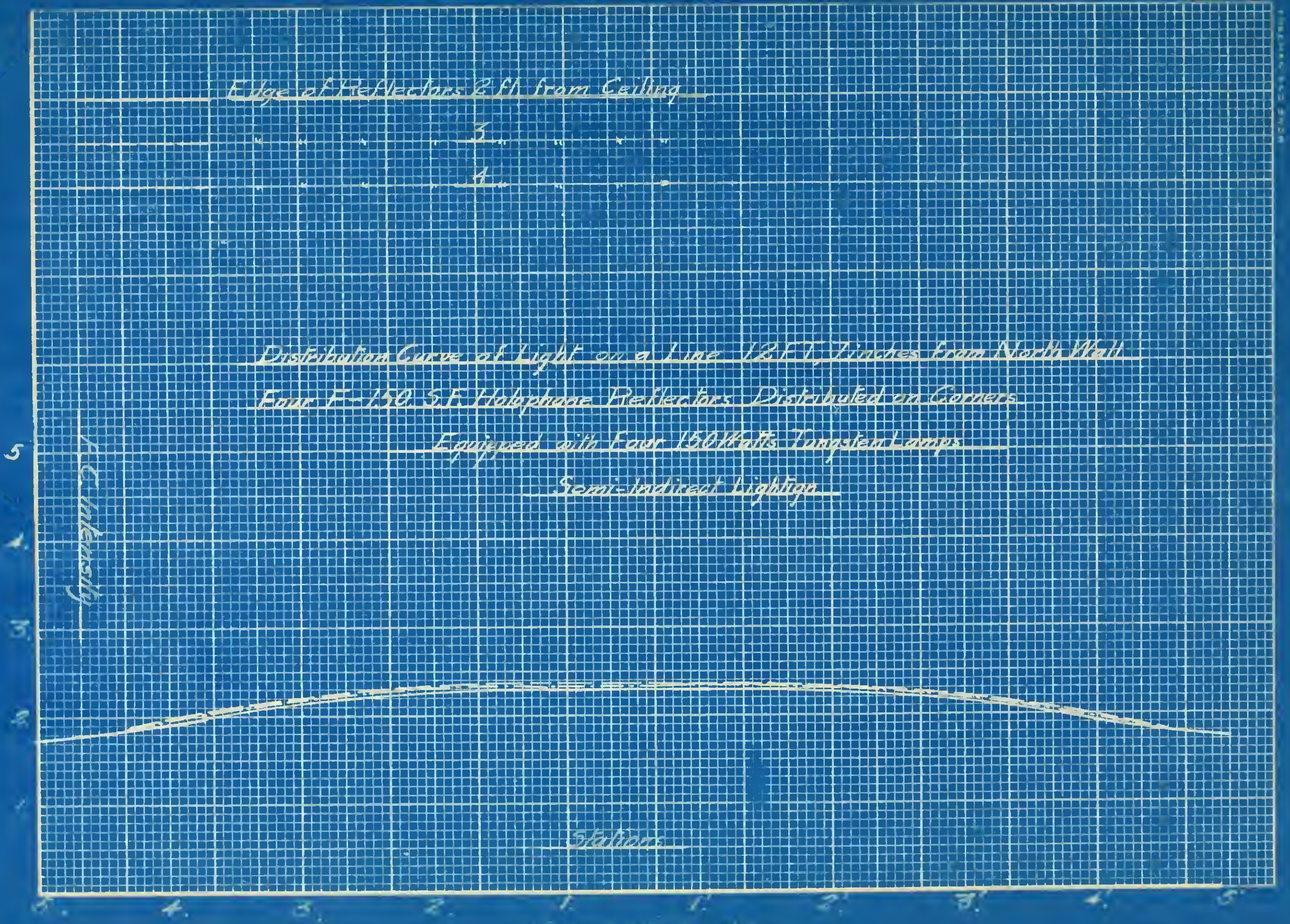
Direct Lighting


Edge of Reflectors 5 ft 8 in. from Ceiling
4 ft 8 in.
3 ft 8 in.
Distribution of Light and Line 5 ft 8½ in from North Wall
Four F-150 S.F. Holophane Reflectors, Distributed on Corners
Equipped with 150 Watts Tungsten Lamps
Direct Lighting
F.C. Intensity
Stations
6.
5.
4.
3.
2.
1.
16.
17.
18.
19.
20.
20'
19'
18'
17'
16'

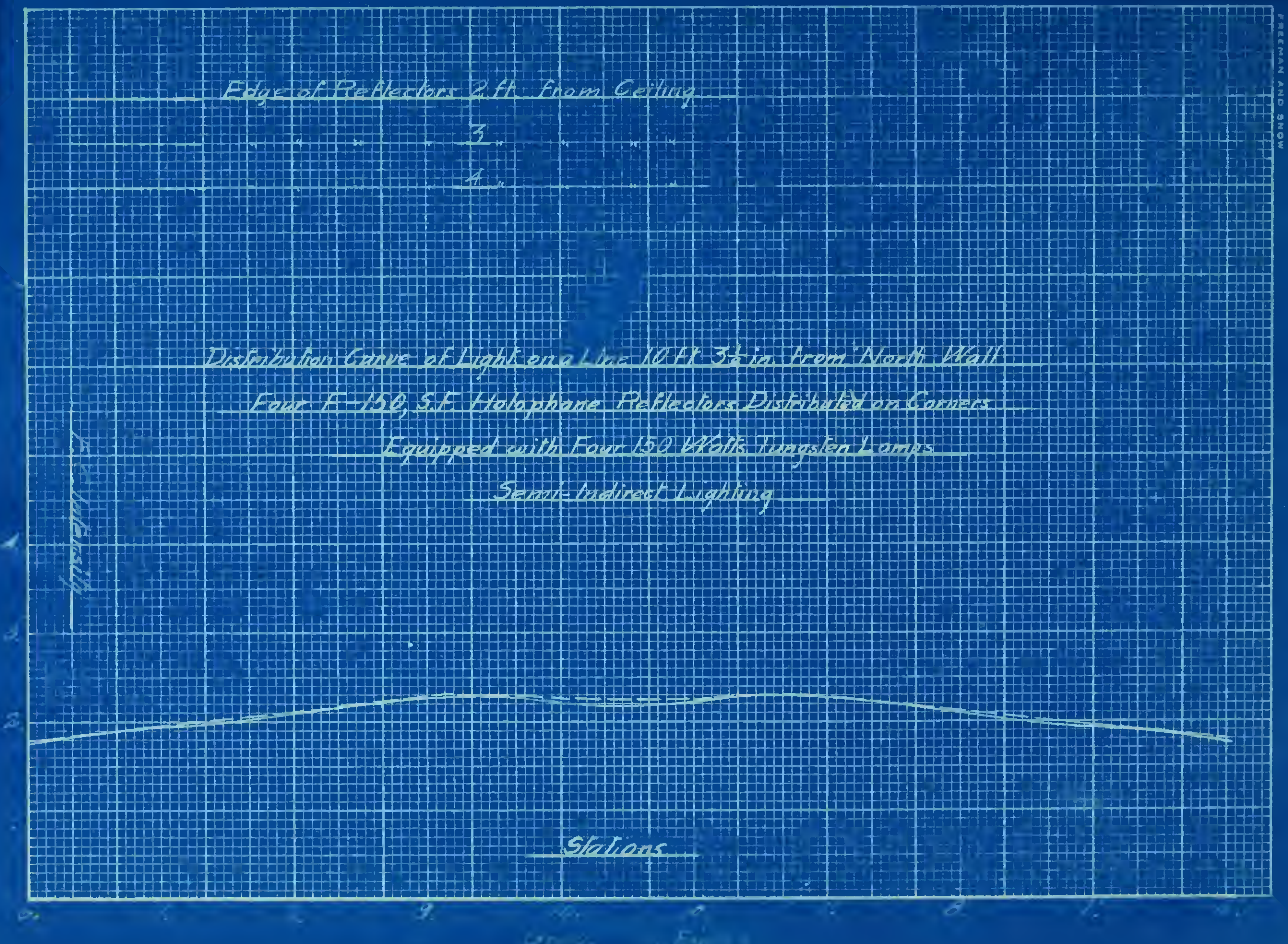

Edge of Reflectors 5 ft 8 in. from Ceiling
4 ft 8 in
3 ft 8 in
Distribution Curves of Light on a Line 3 ft-5 in from North Wall
Four F-150 S.F. Holophane Reflectors Distributed on Corners
Equipped with 150 Watts Tungsten Lamps
Direct Lighting
F.C. Intensity
5
4.
3.
2.
1.
Stations
25.
24.
23.
22.
21.
21'
22'
23'
24'
25

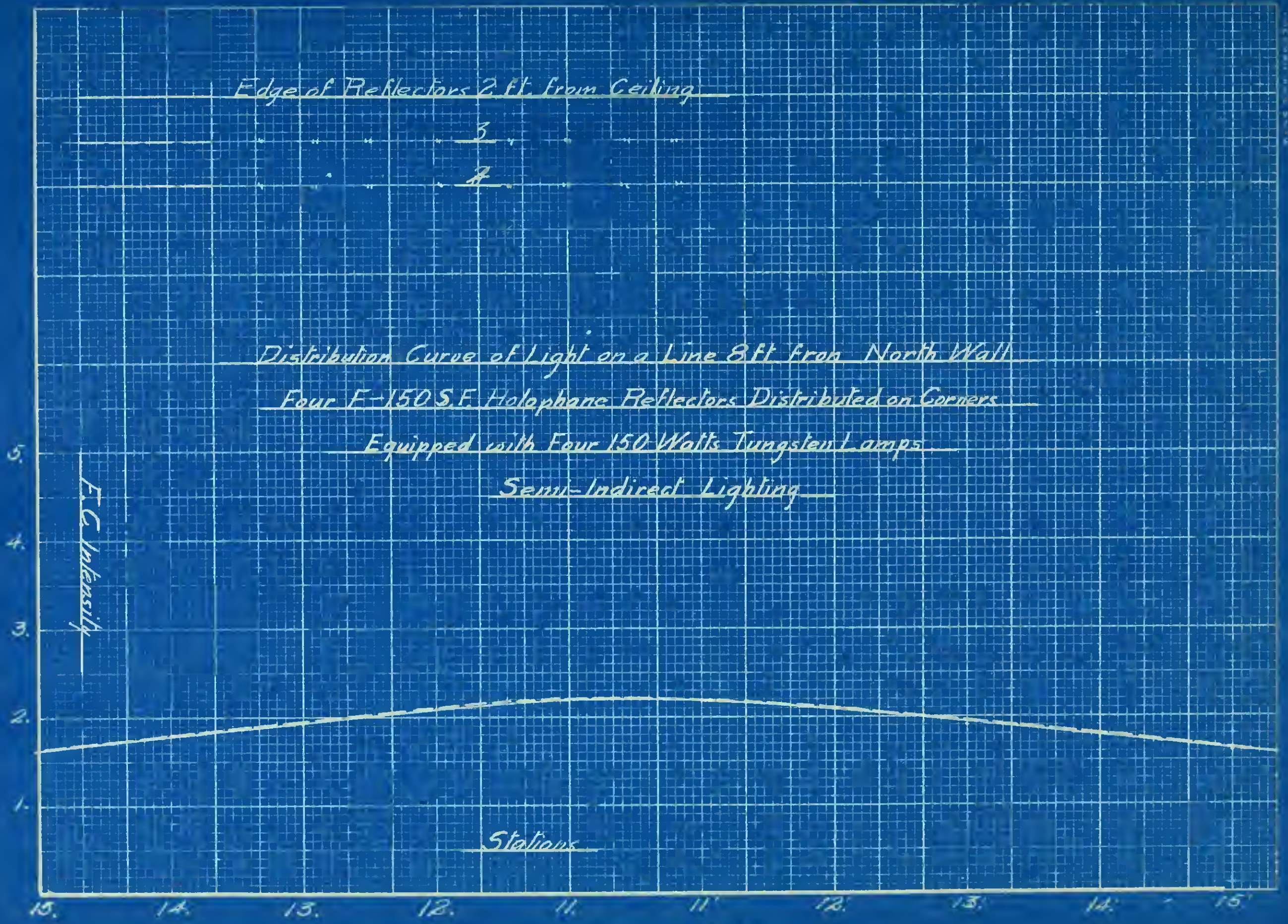

Edge of Reflectors 5 ft-8 in. from Ceiling
4 ft-8 in.
3 ft-8 in
Distribution Curves of Light on a Line 1 ft-1½" from North Wall
Four F-150 S.F. Holophane Reflectors Distributed on Corners
Equipped with 150 Watts Tungsten Lamps
Direct Lighting
F.C. Intensity
5.
4.
3.
2.
1.
Stations
26.
27.
28.
29.
30.
30.
29.
28.
27.
26.

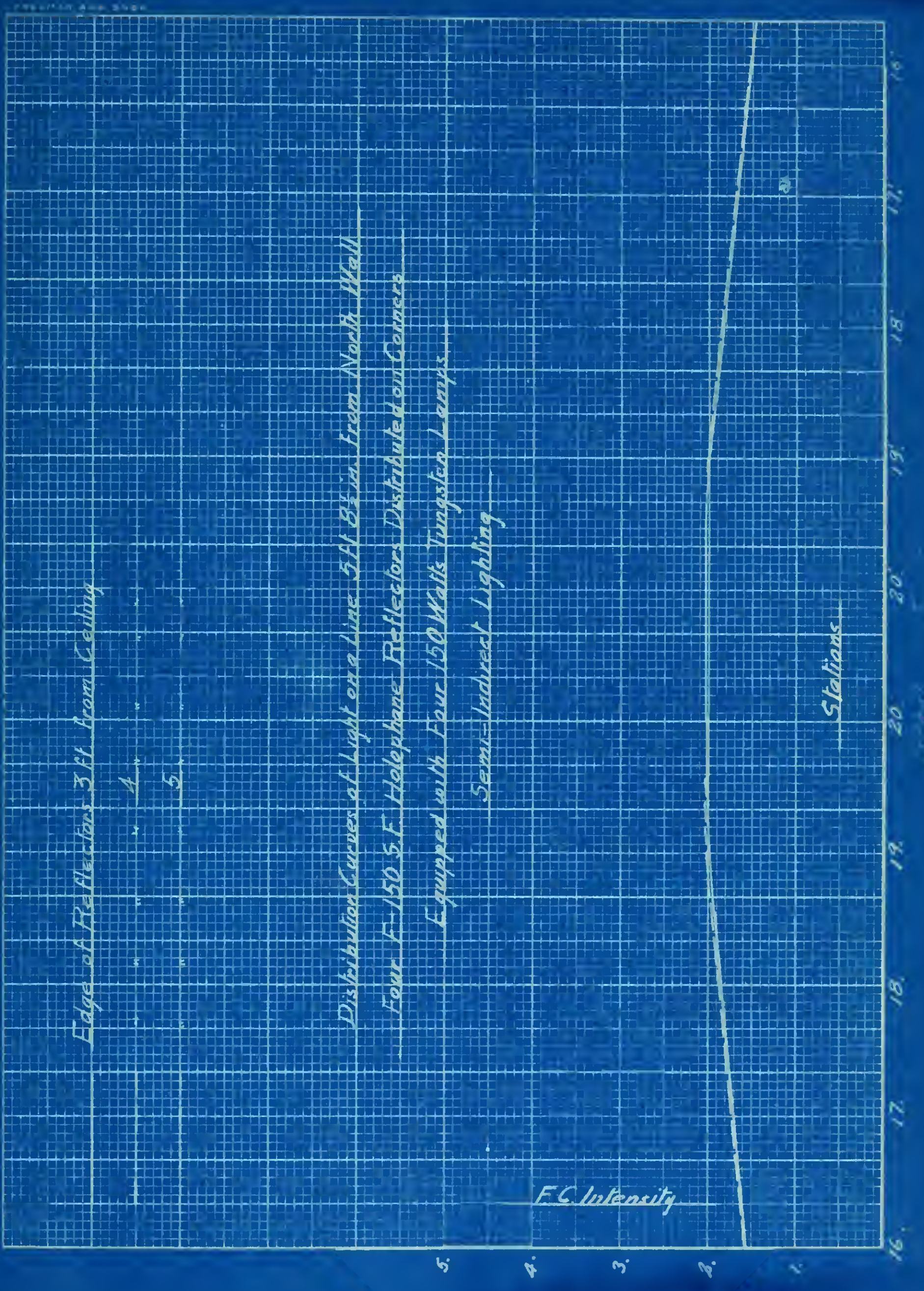
Group VII, F. 4

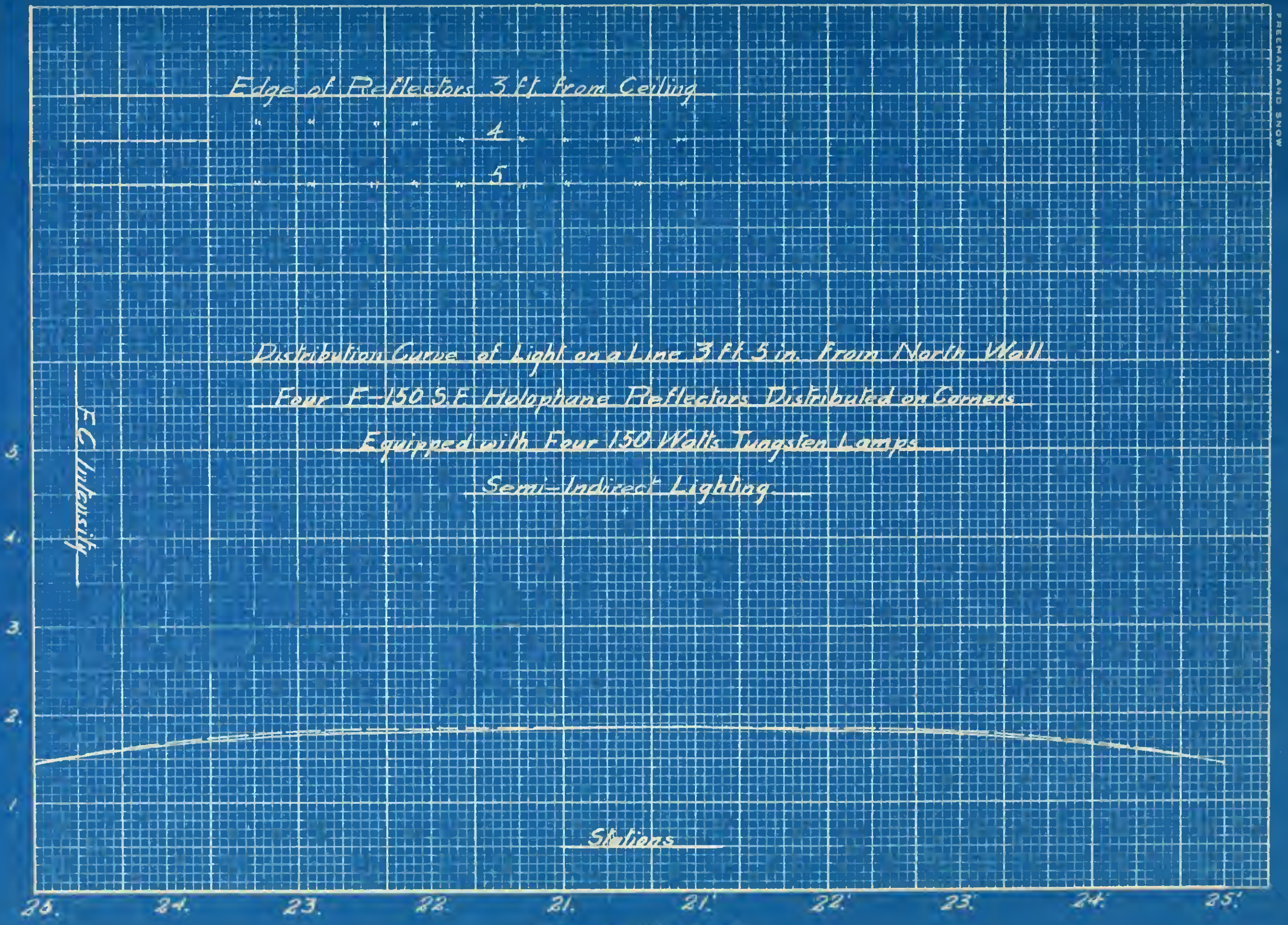


Curve Sheet No. 43


FREEMAN AND SNOW
Edge of Reflectors 2 ft. From Ceiling
3 "
4 "
Distribution Curve of Light on a Line 10 Ft 3½ in. from North Wall
Four F-150, S.F. Holophane Reflectors Distributed on Corners
Equipped with Four 150 Watts Tungsten Lamps
Semi-Indirect Lighting
F.C. Intensity
Stations

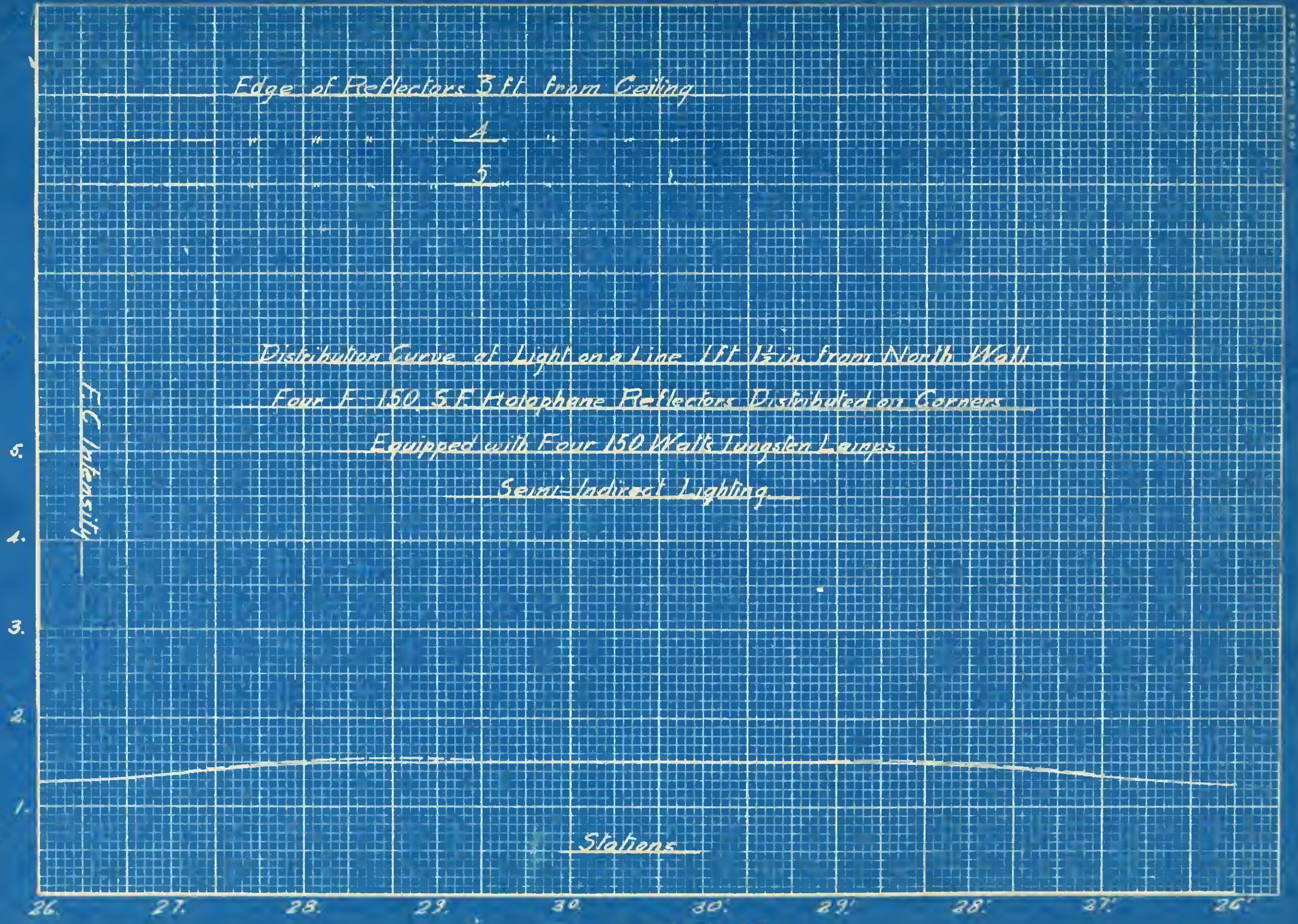

Edge of Reflectors 2 ft. from Ceiling
3
4
Distribution Curve of Light on a Line 8 ft from North Wall
Four F-150 S.F. Holophane Reflectors Distributed on Corners
Equipped with Four 150 Watts Tungsten Lamps
Semi-Indirect Lighting
F.C. Intensity
5.
4.
3.
2.
1.
Stations
15.
14.
13.
12.
11.
11'
12'
13'
14'
15'


Distribution Curves of Light on a Line 5 Ft 8½ in from North Wall
Four F-150 S.E. Holophane Reflectors Distributed on Corners
Equipped with Four 150 Watts Tungsten Lamps
Semi-Indirect Lighting



Group [illegible] Fig. 6

FREEMAN AND SNOW



Group VIII. Fig 48

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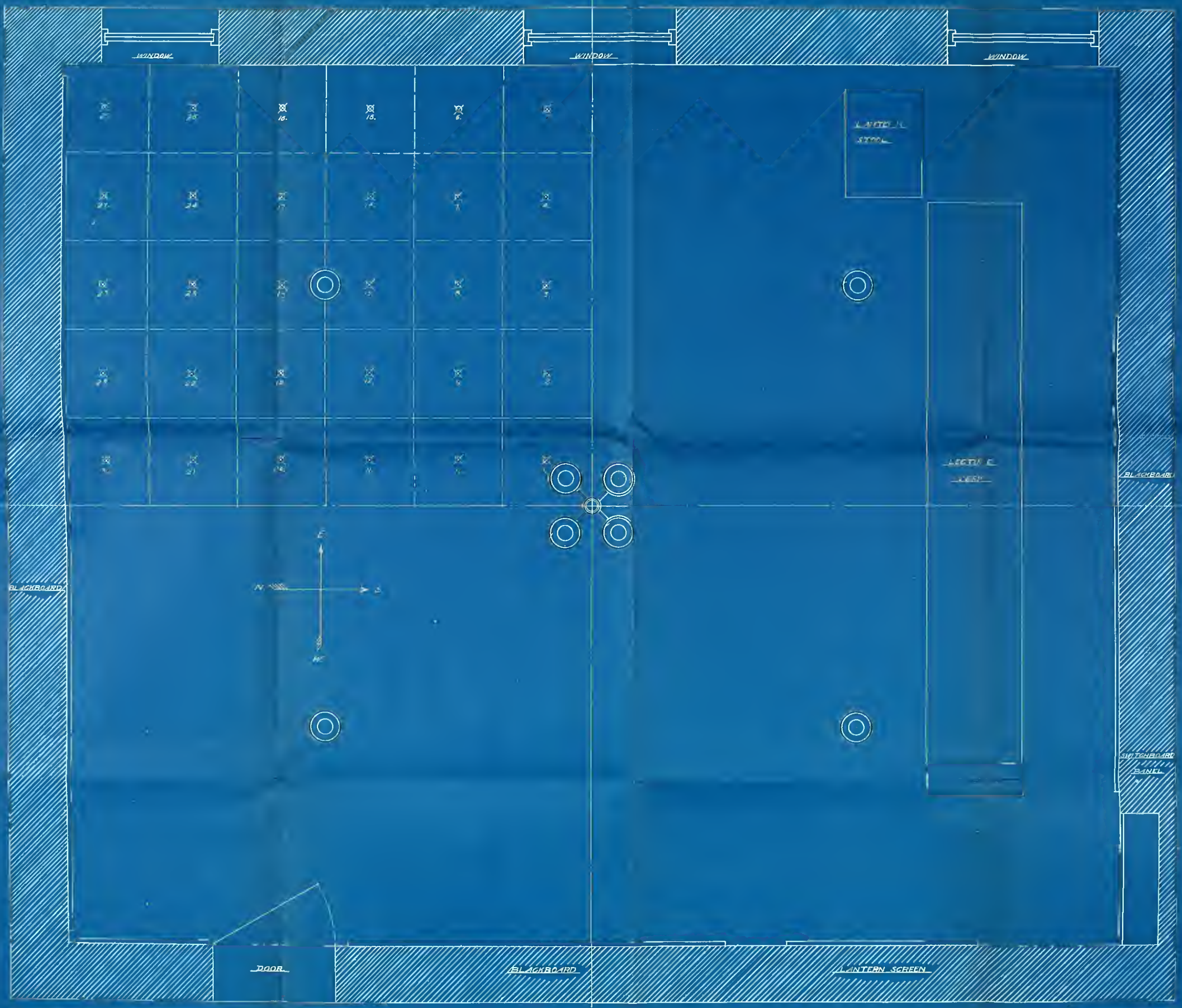
ECHNOLOG



PLAN VIEW

ELECTRICAL ENGINEERING LECTURE ROOM

ARMOUR INSTITUTE OF TECHNOLOGY